PERT COST; HOW CAN THE INDIVIDUAL MANAGER USE IT

by

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PREFACE

PERT COST was chosen as the subject for this thesis because it can be of immediate use to any manager. The particular slant of "How Can the Individual Manager Use It" was selected for two reasons.

First, a military officer will probably be able to use PERT COST only on a personal basis. It is unlikely that anyone in the working environment will know what it is, much less have a useful knowledge of it.

Second, the source materials all concentrate on either the mechanics of the system or its use in a large organization as a formal management tool, complete with computers. This leaves many unanswered questions about how to tie PERT COST into an individual manager's management effort.

This these will tie PERT COST into an individual's management effort and indicate areas where short cuts may be taken to reduce the clerical load on the manager, while maintaining the planning and controlling capabilities of the basic system.

The individual, middle level manager, is the target of this paper. If his appetite for more details on PERT COST is aroused by this paper, he will find ample information in the larger libraries to teach him the mechanics of the PERT COST system.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

PERT COST is a management tool used to optimize the mix of time, resources, and cost for activities having a definite beginning and end.

The purpose of this thesis is to relate PERT COST to the individual manager: "How Can the Individual Manager Use It?" The context of this use is the work situation in which the manager is probably the only one who knows that PERT COST exists. The manager will have no formal computer system, other people to draw his networks, or the accounting and reports to support his effort. His interest is: "How can I use this system to improve the effectiveness, efficiency, and economy of myself and consequently of the organization?"

The scope of this paper does not include a rehash of the mechanics of PERT COST. This type of material is adequately covered in the current literature on PERT COST. Instead, an effort has been made to show the manager how to adapt this system to his personal needs and limitations. The emphasis is on what the manager needs and how he can get it through the use of PERT COST.

The discussion is broken down into four specific areas of

interest for the manager:

1. What can PERT COST do for the individual manager?
2. How are costs used in PERT COST?
3. How can the individual manager plan with PERT COST?
4. How can the individual manager control with PERT COST?

The value of this approach is twofold: First, it will tie together some very lose ends in the current literature on PERT COST. The PERT COST model can be quite useful to the manager on a personal basis even though its maximum potential can only be developed through the use of a formal, computer supported system. Most books emphasize the mechanics of the system and devote little attention to such things as where and how the costs are obtained or how to plan a project with the control of individuals and/or organizational units as a primary consideration.

Second, if individual managers can be encouraged to use this tool in their personal activities, their increased effectiveness will set the example for others to follow and open the door for the full implementation of the PERT COST system in the organization.

CHAPTER I

WHAT CAN PERT COST DO FOR THE INDIVIDUAL MANAGER

The purpose of this chapter is to show that PERT COST is a tool that will satisfy management's needs to plan and control costs of specific projects. Its budgeting and various cost analysis techniques are applicable to all definable operations of the organization.

The following main ideas will be discussed:

1. How as PERT COST developed?
2. What are the objectives of PERT COST?
3. What are the advantages of using PERT COST?
4. Is there any tangible evidence that real benefits have actually accrued from the use of PERT systems?
5. How can PERT COST improve the effectiveness, efficiency, and economy of the individual manager?

How was PERT COST Developed

PERT COST is a managerial system for the planning and control of specific projects. It is a model that enables the manager to determine what must be done, how to schedule the activities, what the best allocation of resources will be, how much of the project

will cost, and how to minimize the total costs. When the planning is completed, the plan becomes a standard against which to measure progress and deviation. Management by exception is taken on those activities that exceed their allowed margin of error. This system is applicable to any project that has specific beginning and ending points. Flow processes may be handled by considering only one phase or cycle of the process as the planning and control entity.

The PERT systems were initiated in 1958 to aid managers in the planning and the control of the three basic variables of large weapons systems development programs--time, cost, and performance.[1] PERT systems are an improvement over the older method of networking, Critical Path Method, which is used by the construction industry. PERT allows the use of statistical probabilities to narrow the margin of error when dealing with uncertainties. The initial use of the PERT system was in the planning and scheduling of activities only.[2]

As the scheduling of activities came under control, managers realized that time, cost, and performance were interdependent variables in all projects and were subject to the same control

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[1]Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide: PERT COST Systems Design (Washington, D.C.: U.S. Government Printing Office, 1962), p. i. (Hereinafter referred to as the Office of Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide.)

[2]Robert W. Miller, Schedule, Cost, and Profit Control with PERT: A Comprehensive Guide for Program Management (New York: McGraw-Hill Book Company, Inc., 1963), p. 27-29. (Hereinafter referred to as Miller, Schedule, Cost, and Profit Control.)

system as the time factor.[1] During the period from 1961 to 1962, with the publishing of the DOD and NASA Guide, PERT TIME was expanded to include the allocation of resources and the planning and minimizing of costs.[2] The DOD and NASA Guide was published to standardize the PERT systems that would involve government contracts and operations. The use of the total PERT COST system was encouraged for all government operations.

Summary

PERT TIME was formalized in 1958. PERT COST, including the allocation of resources, was formalized in 1962. The PERT systems were developed to aid managers in controlling time, cost, and performance variables in uncertain situations.

What are the Objectives of PERT COST

This section will look at the general capabilities of PERT COST and relate them to the needs of the manager and the project. There are three questions that will be considered:

1. What are the requirements of the manager and the project?
2. What are the basic objectives of PERT COST?
3. What kind of questions can PERT COST answer?

Requirements of the manager and the project

Managers.--Managers sit on an iceberg when it comes to managing

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[1]Miller, Schedule, Cost and Profit Control, p. 14.

[2]Miller, Schedule, Cost, and Profit Control, p. 1.

projects. They have problems of visibility, really being able to see what is going on under them; of perspective, what does the whole thing look like; and of realism, what is the real picture, when free of distortion by subordinates reports and interpretations. Managers need a management tool that will:[1]

1. tell exactly what work needs to be performed,
2. allocate resources optimally to minimize the time and cost required to achieve the performance objectives,
3. yield realistic time and cost schedules, and
4. identify areas of potential or actual cost or time overruns in time to take corrective action.

Projects.--There are similar requirements for the execution of projects:[2]

1. What activities are required to accomplish the end objective?
2. What are the inter-relationships of these activities that will effect their sequence?
3. How can the resources be mixed to meet the time, cost, and performance goals of the project?
4. How can the final outcome be predicted with some degree of certainty and confidence?
5. How will changes, controllable and uncontrollable, effect the outcome of the project and how can this effect be offset?

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[1]Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, p. ii.

[2]Miller, Schedule, Cost, and Profit Control, p. 15.

Basic objectives of PERT COST

There are two basic objectives:[1]

1. to provide a significantly more realistic cost estimate for the entire project and
2. to provide a realistic standard, against which project accomplishment can be compared.

These objectives are based on the interdependent relationship of time and cost. Simply stated, this means that the longer an employee works, the more it is going to cost. This simple situation is complicated by the variability of resources, their application to any given activity, and the accumulation of indirect costs, opportunity costs, and penalty costs.

Minimizing total costs.-- The PERT COST model will help the manager determine:[2]

1. the schedule that will minimize the total cost of the project,
2. how to reduce the time schedule while minimizing the increase in the total costs, and
3. the most economical schedule for meeting the project deadline.

Buying time.--Hitting the "panic button" on an entire project because it is running behind schedule is an unnecessary waste of money and is hard on morale. Some of the activities will have

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[1]Miller, Schedule, Cost, and Profit Control, p. 90.

[2]Joseph Horowitz, Critical Path Scheduling: Management Control Through CPM and PERT (New York: The Ronald Press Company, 1967), p. 104. (Hereinafter referred to as Horowitz, Critical Path Scheduling.)

slack, that is, there is more time than necessary to complete them. To "crash" these activities with overtime or more resources is a waste of funds. Other activities are on the critical path, which is the chain of activities in which there is no slack. Any delay in them will effect the project completion date.

The criterion in selecting activities to "crash" is how much does time cost? The time factor may be corrected at no additional cost to the project by switching resources from slack activities to critical activities to buy time on the critical path. Additional project resources may be required, but should be bought only for those activities on the critical path and then the priority of activity support should start at the least-expensive-most-time gained activity and work up to the most-expensive-least-time gained activity, taking into account the new critical paths that may be formed when any change is made to the network.

Saving money.--Money may be saved by extending the time factor. The cost of those activities with the greatest cost per unit of time, usually a day, may be reduced by extending the time available for completing the activity. The cost is lowered by substituting less expensive but slower resources. For example, reducing the overtime used saves the premium wage differential; or using an older, slower machine instead of the more expensive, fast one to do the same job will reduce the allocated cost of

equipment to the project.

The criterion, again, is how much does time cost? Start at the most expensive activity and work down to the least expensive. By carefully selecting the activities to change, the project cost can be lowered until all activities are on the critical path. At this point, further savings can be made only by extending the project completion date.

Questions PERT COST can answer

This list of questions is only a sample of the variety of questions that PERT COST can provide answers for.

1. What must be done?
    a. What activities are required to meet the end objective?
    b. What are the complex, interrelationships or constraints between these activities?
2. What are the time factors?
    a. How long will the project take?
    b. Can we meet our deadline?
    c. Are we on schedule?
    d. What areas are developing potential delays?
    e. How will the delay in a particular activity effect the project completion date?
3. What are the resource factors?
    a. What resources are required?
    b. What is the optimum mix of resources?

c. How should we schedule material deliveries?

d. How should we schedule manpower requirements?

4. What are the cost factors?

a. What is the minimum cost of the project?

b. How can time be bought or money saved?

c. What is the effect of potential cost overruns?

5. What is the probability of achieving the time, cost, and performance goals?

6. What effect will a change have on the project?

Summary

The manager requires visibility and perspective of a project. The project itself needs detailed analysis, planning, and control. PERT COST is aimed at the planning and control of costs and, secondly, at providing a standard against which project accomplishment can be measured for control purposes. This system can answer many questions that come up in the planning, execution, and control of a project.

What Are the Advantages of Using PERT COST

The previous section implied many advantages of the PERT COST system while discussing its objectives. This section will identify and expand on nine specific advantages of the PERT COST system.[1] The following list summarizes the advantages to be discussed:

1. More Effective Planning

2. Shows Relationships

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[1]This listing is an adaptation and expansion of the advantages as given by Horowitz, Critical Path Scheduling, p. 10.

3. Pinpoints Problem Areas
4. Improves Communication
5. Better Resource Allocation
6. Provides Simulation Model
7. Allows Management by Exception
8. More Effective Control
9. Focuses on Costs

More effective planning

It provides a comprehensive planning descipline, which requires the manager to do careful, detailed planning. By aiming at the end objective, all activities and decisions are co-ordinated toward the most effective, efficient, and economical way of completing the total project under the given constraints.

Shows relationships

All activities are related to achieving the project goal. Each activity will be individually evaluated for its contribution to the end item. If its contribution is neutral or negative, it will be eliminated. Likewise, those activities that are positive but are not a necessity may be eliminated as cost constraints require.

The relationship of activities to each other is identified. This relationship determines whether a group of activities must be carried out in series or may be carried out in parallel. One way of shortening the overall project time is to maximize the concurrency of operations.

The coordination of all activities is through their time relationship, individually and to each other, and to the project as a whole. There are two basic times associated with each activity: normal and crash. Sometimes it is better for the project as a whole to crash one or two activities in order to allow other larger, more sensitive ones to be carried out at their normal pace.

Resources for each activity are constrained by the time and cost limitations for the project. Within these outside constraints, resources will be related to achieve the time, cost, and performance goals of the activity at the minimum cost.

Pinpoints problem areas

As the above relationships are worked out many problems will be recognized and solved before they become crises. During execution, an imbalance in the interrelationships will quickly pinpoint problem areas because time resource, or cost schedules will not be met.

Improves communication

The manager learns of the critical areas by doing his homework on the PERT COST model. This gives him the specific facts and figures he needs to properly explain the situation to subordinates in order to work out the needed solutions. He is also better prepared to justify requests to higher authority for additional resources.

A summary network or "fragnet" (fragment of a network) can be

an ideal visual aid in discussing problems. If it is kept simple, it can be easily understood by others.

Better resource allocation

Manpower, materials, equipment, money, and time can all be related to each other on this model. The optimum mix will be that which achieves the time and performance objectives at the least total cost.

The plan can be organized to best use scarce resources. The plan may even have to be built around the use of a scarce resource.

Resource requirements may be leveled so that overhead costs of inactive resources will be minimized. Slack activities will be juggled to utilize resources when critical activities do not require them in order to get maximum use from the minimum resource level.

Provides simulation model

The use of the PERT COST model is in fact a simulation of what management expects to happen. Changes and alternative courses of action may be worked out on the model to determine their overall effect on the project. The effects of uncontrollable forces can be analyzed and contingency plans prepared.

The PERT COST model can also be used to develop a proposed project: to determine its feasibility, cost, and time factors.

Management by exception

PERT COST identifies the critical path of operations, and

sets parameters on other activities which limits their slippage to a specified amount. Management needs to watch the critical path closely, but the other activities get attention only when they exceed their margins of slack.

More effective control

Management effort is concentrated on the sensitive areas which effect project goals. The detailed planning and discussion, the reduction of the plan to writing, and the defining of individual responsibilities, gets everyone on the right track to start with. The completed PERT COST model then becomes the standard against which to compare individual performance in the methods and rate of project accomplishment.

Focuses on costs

This model gives management an effective tool for focusing on the cost of projects. The common denominator of all decisions is cost, and the ultimate output of the model is the project cost.

During the planning and execution phases, projected and actual costs can be compared with the value of the end item or the imposed budget constraints. This will allow management to take timely corrective action or seek additional resources prior to a crisis.

Is There Any Tangible Evidence That Real Benefits Have Actually Accrued From the Use of PERT Systems

Some information has been developed to show the effectiveness

of PERT systems in saving time and money. Information in the following areas will be presented:

1. How bad is the situation?
2. How has PERT helped government operations?
3. How has PERT helped commercial operations?

Situation

Two studies were made on major weapon programs during the 1950's to determine their effectiveness on cost and time factors. The RAND study of twenty-two major military development programs revealed that cost overruns of 200-300 per cent and time overruns of 33 percent to 50 percent were not the exception but the rule. A Harvard study during the same period on twelve weapon programs gave an average cost overrun of 32 percent and a time overrun of 136 percent.[1]

These variances are accounted for by the following factors:[2]

1. The high degree of technical uncertainty in the programs, made time and cost estimates uncertain and unreliable.
2. The competitive situation of companies bidding for these contracts, made them present their most optimistic bids.
3. Frequent changes in program direction resulted from the lack of clear-cut priorities for the technical objectives.
4. Management lacked the planning and control techniques necessary for the proper management of large complex programs.

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[1]Miller, Schedule, Cost, and Profit Control, p. 10.

[2]Miller, Schedule, Cost, and Profit Control, p. 13.

The PERT systems are the outgrowth of this situation. They were designed to give management a tool for handling large, complex programs; however, they are equally suited to small projects also.

PERT has helped government operations

Cost Reduction through Better Management in the Federal Government, published by the Bureau of the Budget in April, 1963, cited the following cases of cost reduction or schedule improvement attained through the use of PERT systems:[1]

1. The Navy, through PERT COST, was able to save $250,000 out of a contractor reported cost overrun of $850,000.
2. Through a routine PERT TIME analysis the Army was able to prevent an estimated $100,000 of additional expense caused by a schedule slippage.
3. When an Air Force development program was integrated on a PERT TIME network, a thirty-six week delay was discovered and reduced to eight weeks, giving a substantial reduction in costs.
4. NASA was able to deny a contractor's request for overtime authorization, on a number of specific tasks, based on PERT reports showing that some of the tasks had been completed and that the others had slack which eliminated the need for rush work.
5. Through PERT TIME, the Atomic Energy Commission was able to decrease shutdown times on two different reactors by

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[1]Miller, Schedule, Cost, and Profit Control, p. 166.

10-15 percent. On one reactor, this saved an estimated $3,000 every four weeks. On the other reactor, this saved about $14,500 every six weeks.

PERT has helped commercial operations

J. W. Pocock, of the Booz-Allen Applied Research Group, reported in the December, 1962, Operations Research, the results of an extensive study of the savings achieved through PERT systems. Some of the more significant savings were as follows:[1]

1. Du Pont reduced maintenance shutdown time by 37 percent in one plant and, thereby, gained one million pounds of production.
2. International Minerals & Chemicals reduced maintenance shutdown time on a mine hoist by 27 percent and saved $100,000.
3. Catalytic Contruction Company used PERT systems on forty-seven construction projects and had an average time reduction of 22 percent plus an average reduction in expediting costs of 15 percent.
4. Sun Maid Raisin Growers used PERT to properly time the construction of a plant to the growing season. They devreased the time by 25 percent and saved $1,000,000.

Summary

In the 1950's, military weapons programs were having cost overruns of 200-300 percent and time overruns of 33 percent to 50 percent as an average. The reson given was the lack of

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[1]Miller, Schedule, Cost, and Profit Control, p. 169.

management tools to effectively deal with the size, complexity, and uncertainty of these programs. PERT COST was developed to provide management such a tool.

In government operations, savings as high as twenty-six weeks of time and $250,000 have been recorded. In commercial operations, savings of 25 percent in time and $1,000,000 have been recorded.

How Can PERT COST Improve the Effectiveness, Efficiency, and Economy of the Individual Manager and His Organization

The individual manager probably does not deal with figures as impressive as twenty-six weeks delay or $1,000,000 savings; but a 10-20 percent savings in time and costs certainly will not go unnoticed by those around him.

This discussion will be broken down into three subsidiary questions:

1. What benefits will accrue to the individual manager?
2. How can the individual manager acquire and use PERT COST techniques?
3. How can the manager extend the use of PERT COST throughout his organization?

Benefits that will accrue to the individual manager

Effectiveness.--He will be able to improve the effectiveness of himself and the organization. The improvement in the effectiveness of the organization will result from his increased

effectiveness.

The application of PERT COST to his own activities will allow him to accomplish more with greater effectiveness, efficiency, and personal economy of management effort.

PERT COST applied as a homework tool will show him the right questions to ask of subordinates to guide and improve their planning and control efforts. It will also give him the right answers to questions from his superiors and justification for requests of his superiors.

Efficiency.--He will be able to increase the efficiency of the organization by increasing his own efficiency as a manager. More time will be spent on effective planning and control and less on false starts and crisis management.

By careful PERT analysis of the operations of his organization, he can weed out the distractors and less important activities, increasing the output of the organization per unit of resource input.

Economy.--By reorganizing activities, the manager can buy time or save money to meet his budget constraints or cost reduction program. PERT COST gives him a comprehensive tool for the planning and controlling of costs, allowing him to optimize costs for any given situation.

Individual managers can acquire and use PERT COST techniques

The PERT COST mechanics are relatively simple to learn, and

require only simple arithmetic and common sense. These mechanics are readily available in a number of books at most large libraries and in the directive systems of some government and military organizations.

To get the feel of PERT COST, the manager should first apply the system to some of his own, personal projects. This will allow him to become familiar with the problems and methods of applying the PERT COST techniques to actual situations.

Next, he should use PERT COST as an analytical tool to sketch out, for his own knowledge and understanding only, some organizational projects in which he is involved. A detailed approach to working out these larger projects is likely to make the clerical work more burdensome than the results are worth for an individual. The manager can reduce the clerical burden by concentrating on key points, i.e., a summary of the major activities and control points in the project accomplishment; with some detail of key problem areas, use of critical resources, or sensitive areas of co-ordination between different organizations.

The manager may desire to pattern some graphic aids on the network analysis or the resource and cost report graphs. This will help him to explain the problem and to focus the group discussion on specific facts and situations. If these aids are kept simple and explicitly clear, there will be no problem of understanding by those who are not familiar with the PERT COST techniques.

Managers can extend the use of PERT COST throughout their organizations

The individual manager has two routes by which he can extend the use of the PERT COST discipline throughout his organization. One is the formal change approach which would include staff studies, formal briefings, and the formal change procedures, as well as additional computer time and programs. The other is the informal approach of setting the requirements for the information and demonstrating the use of PERT COST and its value through personal use, ultimately moving into the formal change stage. In the longrun, the informal approach, as outlined below, will yield the best results.

The questions raised by PERT COST are valid management questions regardless of the method used for deriving or recording the information. Subordinate managers can handle the same information in a number of other ways. Don't rock the boat unnecessarily by imposing these techniques.

The subordinate managers will be quick to recognize the manager's increased ability to ask the right questions and spot the problem areas. In response, they will start developing the required information in their own ways.

If the manager is careful in his choice and use of PERT COST graphic aids, he can demonstrate the simplicity and convenience of the specific PERT techniques during normal project discussions without talking down to his subordinates. As they see how these methods are used, they will begin evaluating their own procedures

for ways to cut the cost and improve the convenience. If the PERT COST methods are better, they will adopt them voluntarily.

As questions arise from the subordinates, the manager should be prepared to answer them and to aid them in learning how to use the system. The PERT-O-GRAPH kit approach would be a useful starting point, see Appendix A. Not everyone will be interested in using the system, but any change will be an improvement. As a few adopt the system, work with it, and learn of its advantages, they will sell it to their employees and talk it up with their peers. If there are truly significant advantages to using it, the holdouts will soon have to start using it in order to keep up.

The natural extension of this approach is the desire for greater detail, scope, and efficiency in PERT activities which brings in the formal computerized PERT COST system.

PERT COST is only one management tool out of many in any organization and must be properly co-ordinated with the other tools, such as the existing management information system, internal operating procedures, accounting and cost accounting techniques, and budgeting procedures.[1]

The best way to integrate this tool is through knowledgeable, motivated subordinate managers who desire to work out the co-ordination and realignment problems.

Summary

Through PERT COST, the individual manager can increase his personal effectiveness, efficiency, and economy and consequently

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[1]Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, p. ii.

that of the organization.

The individual manager can acquire the mechanics of PERT COST from numerous books and directives, with only simple arithmetic and common sense. The skills should be practiced first on personal projects and activities, then used for personal analysis of organizational projects. The results of this analysis can be used in graphic aids to focus the discussion of the specific problems.

PERT COST should not be forced onto an organization. Informal demonstration, use, and proving that it has significant advantages over current methods, will cause its acceptance and ultimate expansion into a formal computerized PERT COST management system.

Summary

Through PERT COST the individual manager can increase his personal effectiveness, efficiency, and economy and consequently that of his organization.

PERT COST is an evolutionary development of the Critical Path Method (CPM) used by the construction industry. PERT TIME was formalized in 1958. PERT COST, including the allocation of resources, was formalized in 1962.

The manager requires visibility of and the perspective for a project. The project needs detailed analysis, planning, and control. PERT COST is aimed first at the planning of costs and second, at providing a standard against which project accomplishment can be measured for control purposes.

The PERT systems were developed to aid managers in controlling time, cost, and performance variables in uncertain situations. In the 1950's, military weapons programs were having cost overruns of 200-300 percent and time overruns of 33-50 percent as an average. The reason given was the lack of management tools to effectively deal with the size, complexity, and uncertainty of these programs.

PERT systems have yielded savings in both government and commercial operations. In government operations, savings of twenty-six weeks and $250,000 have been recorded. In commercial operations, savings of 25 percent in time and $1,000,000 in cost have been realized.

The individual manager can acquire the mechanics of PERT COST from numerous books and directives, with only simple arithmetic and common sense. The skills should be practiced first on personal projects and activities, then used for personal analysis of organizational projects. The results of this analysis can be shown in PERT COST graphic aids to focus discussion on the specific problems.

PERT COST should not be forced on an organization. Informal demonstration, use, and proof that it has significant advantages over current methods will promote its acceptance and ultimate expansion into a formal computerized PERT COST management system.

CHAPTER II

HOW ARE COSTS USED IN PERT COST

PERT COST is designed to help the manager make more realistic cost estimates. To do this, costs are integrated into the planning process at every step. Money is a critical resource and is treated as such for each activity. Cost and time are the measures of optimization in the PERT COST model. Performance is a qualitative factor operating concurrently with time and cost.

The purpose of this chapter is to explain how costs are integrated into the PERT COST model. The emphasis will be on some general ideas and concepts that are not always clearly presented in the general references available. The mechanics of using costs in the PERT COST model are adequately covered in many texts.[1]

The discussion will answer these questions:

1. What is the cost objective?
2. How is the cost objective reached?
3. How does the Work Breakdown Structure assist the manager?
4. How can the individual manager acquire the cost data?

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[1] A simple, manual model is given by Horowitz, Critical Path Scheduling, pp. 104-37. Moder and Phillips present three methods of handling the time-cost relationship using manual, mathematical algorithms, and linear programming, Project Management, pp. 107-63.

What Is the Cost Objective

The cost objective will be described by stating it and discussing the elements of the cost mix, constraints on the situation, and the optimization of the cost mix.

The cost objective is to minimize the total expense for and caused by, the project. A project is usually only one of many activities of an organization. It has certain expenses that must be incurred, if the project is to be accomplished. In addition, the project effects other activities around it such as displacing employees from their normal work areas, closing down a sales operation, or limiting the amount of warehouse space normally available. These interferences cause additional expenses in the form of new telephone installations, additional transportation for work, lost profits from lost sales, increased warehousing expense from slowing down the turnover of stock or the rental of additional warehouse space. the PERT COST model will minimize this total package of expenses.

Elements of the cost mix[1]

See figure 1 for a graphic display of the elements of the cost mix.

Direct costs.--These are all of the costs that are readily connected with the project. Generally they will be for labor, materials, equipment, and other services. The amount of direct costs varies directly with the type and quantity of the specific resources used. They are controllable by the project management

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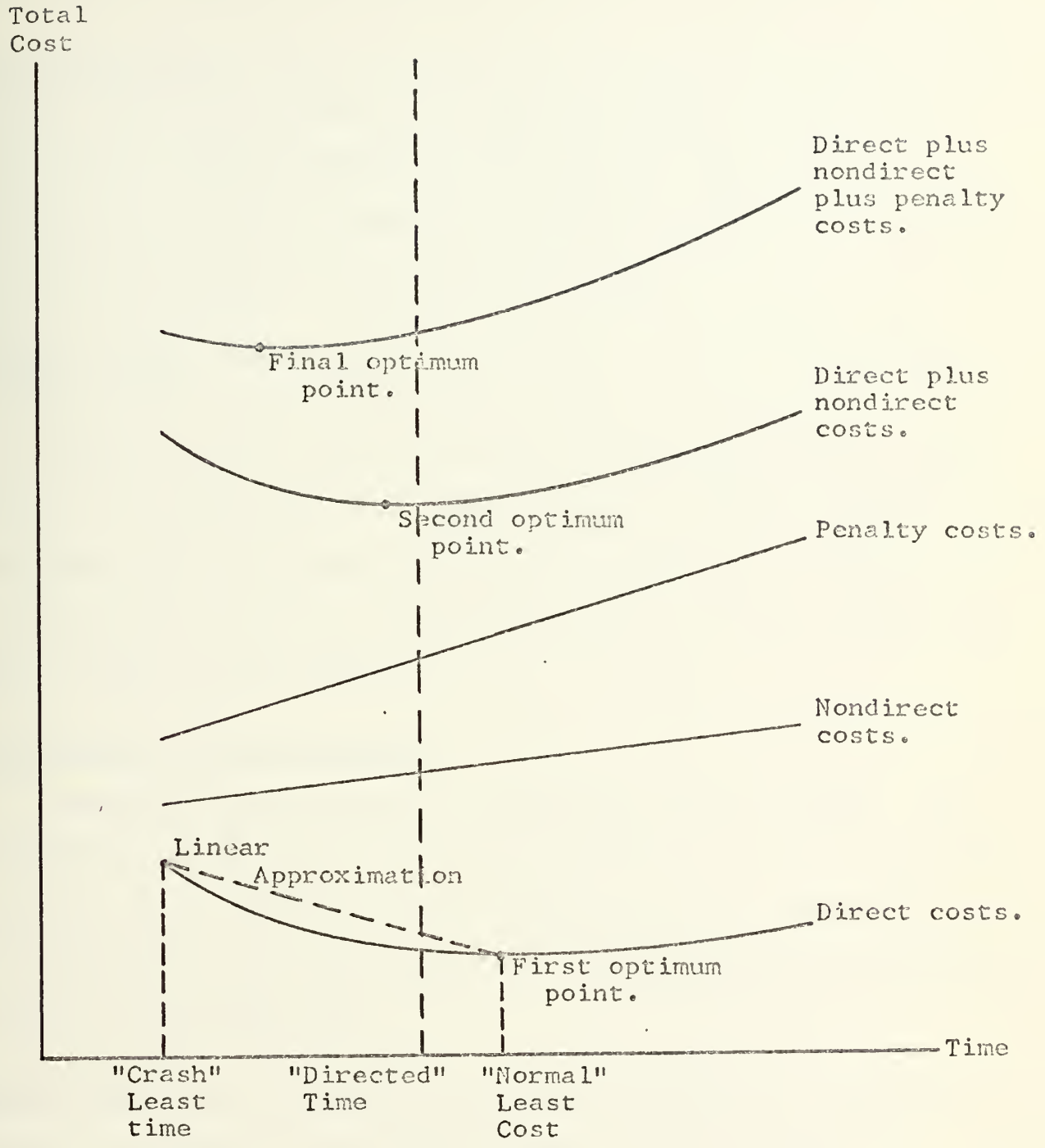
[1]Miller, Schedule, Cost, and Profit Control, p. 123.



Source: Adapted from Miller, Schedule, Cost, and Profit Control, p. 124.

Fig. 1.--Time Cost Relationships for a Project

and may be varied to minimize the cost of the resource mix.

Nondirect costs.--Those costs that are not easily linked to the project and are assigned on a fair share basis. These costs include the overhead expense of the organization, such as expenses for general managers and administration. These expenses are not controllable by the project managers.

Penalty costs.--These are the additional costs, to the overall organization, caused by the inconvenience of the project such as lost profits or the rental of temporary warehouse space. These costs may be absolute as in constructing a temporary building, or they may vary with time as in the loss of profits. The project managers do not control these costs except in their planning and use of time for the project.

Constraints on the situation

There are two classes of constraints on any project. The "absolute" constraints[1] such as the production rate of a machine, the limits of technology, or a limited resource. The other class is "directed" constraints which put arbitrary limits on resources or the use of technology.

Least cost.--If there are no constraints on time or resources, there is one least total cost at which the project may be accomplished. This is the point of maximum dollar efficiency: the greatest value of output per value of input. Below this

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[1]The "Most Efficient Plan" and the "Shortest Time Plan" are further discussed by the Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, p. 102.

least cost, the project cannot be completed.

Least time.--If there are no outside constraints on resources or costs, there is one least time in which the project can be completed. This point will maximize the output of the resources regardless of efficiency. At this point, an addition of any resource will not decrease the amount of time required to complete the project. At any duration less than this, the project cannot be completed.

Normal time.--This is the way the activity is usually performed without specific outside restrictions. This point probably isn't the most efficient, least cost, point at which the activity could conceivably be performed.

Crash time.--This is the minimal time in which it is practical to perform the activity. At this point, the marginal cost of the resources far outweigh the value of the marginal output. Normally management will not pass this practical limit on time.

Directed time.--This is the time objective set for the project by a customer or higher authority. It may be derived through the PERT COST model and be the least cost point or it may be imposed on the situation and be any point between the least cost and least time points, inclusive of them.[1]

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[1]The "Directed Date Plan" is discussed further by the Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, p. 102.

If the probability characteristic of PERT COST is to be used, the normal, crash, and directed time would be the same as the pessimistic, optimistic, and most likely times.

Optimizing the cost mix

The cost mix may be optimized in either of two ways. First, the absolute, global, minimum for total costs may be determined. Second, a relative minimum for any given set of constraints may be derived, giving the least cost for those given conditions.

Reducing total costs.--Variable nondirect and penalty costs are minimized by buying time with direct costs up to the point that the marginal increase in direct costs per day equals the marginal increase in variable nondirect plus penalty costs per day. For example, if variable nondirect plus penalty costs were $500 per day, variable direct costs could be increased up to $500 per day to save the next day from the variable nondirect plus penalty costs. If it cost $300 to save one day, $200 in nondirect plus penalty costs would be saved, reducing total costs by $200. If it cost $500 to save one day, nothing would be gained by it. If it cost $600 to save one day, total costs would be increased by $100 if the day were saved.

Time is bought at the cheapest price possible. Only selected activities will be shortened, in order to minimize the additional variable direct expenses and to maximize the reduction in variable total costs. If other activities are shortened, total cost will not reach the least cost point. Only those activities that are on the critical path will effect the project completion date. To shorten slack activities is just wasting money, as they do not effect the final date, which

effects the amount of the variable nondirect and penalty costs. Within the critical path the most time can be gained, and thus the biggest reduction in total costs, by starting with the activity with the lowest cost-per-day-of-time-reduction. For example, if one activity costs $250 per day to reduce and another costs $300 per day to reduce, two days reduction in time for the $250 activity can be bought for $500 vice one day for the $300 activity.

The total cost amounts derived from this process should be plotted in a total cost curve, as in Figure 1. This makes it easier to determine which side of the minimum cost point the procedure starts on. If the second cost point is above and to the left of the first, the time must be extended to reduce the total costs. This is best accomplished by starting with the most expensive cost-per-day-to-reduce activities, thereby, reducing the direct expenses by the most per day of extension, while minimizing the time extension and, thereby, minimizing the increase in variable nondirect plus penalty costs.

Reducing time.--Reducing time is accomplished in the same manner. That is, by buying time from the least expensive cost-per-day-to-reduce activity on the critical path. Total costs will increase to the left of the minimum cost point, but if the least expensive activities are used, the increase will be minimized. The result will be the minimum total cost for that given time condition.

Summary

The cost objective for the project is to minimize the total expenses for the project, or caused by it.

The cost mix to be optimized is made up of three elements. Direct costs which vary as the resources vary and are controllable by the project management. The nondirect costs, which are allocated to the project and may vary with the passage of time. Penalty costs are those costs caused by the project such as the loss of profits on missed sales. Nondirect and penalty costs are not controllable by the project management.

Constraints on the situation put absolute and practical limits on the ranges in which the total cost can vary. The least cost and least time points are the minimum points at which the project can be accomplished. The normal and crash points are the extremes of the practical operating situation. The directed point is arbitrary and imposed by the customer or higher authority.

The cost mix is optimized by buying time with variable direct costs, along the critical path, to minimize variable nondirect plus penalty costs. The point at which the marginal increase in variable direct costs equals the marginal increase in variable nondirect plus penalty costs is a global, least cost. Past this point, the minimum additional cost for the given constraint can be determined.

How Is the Cost Objective Reached

The cost objective is reached by job-costing each activity, by obtaining the allocated nondirect costs and the penalty costs,

and by budgeting the entire system. The identifing, obtaining, and optimizing of these costs follows a specific procedure during the development of the PERT COST model.

Job-cost and budget system

Job-cost system.--Each activity is costed out in detail for two time points. First, the least cost time point is determined for the cheapest, most efficient operation. Second, the least time point is determined for use in crashing the activity. Each activity is evaluated for its direct costs, including men, material, and equipment, and its indirect costs, such as supervision, insurance, and storage space costs.

Nondirect and penalty costs.--Those costs that are allocated to, or caused by, the project will usually be handled at the top level by the project manager. If these costs effect only a specific series of activities, they should be assigned to that activity or work package to use in its sub-optimization process.

Budget system.--The activity, nondirect, and penalty costs are then combined into a budget for the entire project. The budget will be made up of the least cost data, then adjusted to meet the constraints of the situation, through the PERT COST model.

Procedure

The PERT COST procedure makes three passes through the project organization to arrive at the final total cost estimate

in an orderly manner. The project organization is called the Work Breakdown Structure which will be discussed in detail in the next section.

Down.--The first pass goes from the top to the bottom of the project. The objective of this pass is to organize the project into work packages and activities. This defines the specific activities to be costed out and assigns responsibility for their achievement and cost.

UP.--The second pass goes from the bottom to the top of the project. The lowest activities are networked and costed out and then passed up to the next echelon for their networking and cost operations, and so on to the top of the project. Each activity and work package is sub-optimized for their known costs at the least cost and least time points.

At the top, the project management will apply the work package costs to the summary network, along with the additional nondirect and penalty costs. This summary network will be adjusted to the least cost point and the crash point determined. At this stage, the project's least cost time will be compared with the time constraints placed on the project. If the least cost time is less than the directed time, the project will remain as is. If the least cost time is greater than the directed time, the cost of the project will have to be increased to buy the necessary time down to the directed time point. The crash points of the various work packages will be used to adjust the time

factor.

Down.--The final approved plan will then be passed back down the project organization for readjustment, to the directed time constraint, and the execution of the project.

Summary

The cost objective is reached by first organizing the project and identifying those responsible for the accomplishment and cost of the specific activities. Second, each activity and work package is networked and job-costed and sub-optimized at the least cost and the least time points, and then passed up to the next echelon of the project, and so on. Each higher echelon will continue the process and accumulate least cost and least time budgets for the activities and work packages. Project management will consolidate work packages and add the nondirect and penalty costs into a final least cost and least time network and budget. If the least cost time point is greater than the directed time, time will be bought, down to the directed time point. Third, the final directed time plan will then be passed back down the organization for work package and activity adjustment and execution.

How Does the Work Breakdown Structure Assist the Manager

The Work Breakdown Structure is probably the most important one step in the PERT COST model for the manager. The project organization, networking, cost optimization, and reporting are all organized on it or correlated with it.[1]

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[1]Some basic aspects of the Work Breakdown Structure are discussed by Russell D. Archibald and Richard L. Villoria,

The pertinent points for this section are:

1. Definition of a Work Breakdown Structure.
2. Criteria for its construction.
3. Definition of and criteria for the construction of work packages.

Figures 2 and 3 are a graphic representation of the following material.

Definition of a Work Breakdown Structure

The Work Breakdown Structure is the hierarchical organization of the project. It is started at the top with the definition of the end product. The project is broken down into its major parts keying on the end product and the supporting products required in the production of the end item.

The end item is the goal to be accomplished. All resources flow through the project plan to the personnel organization and work packages to the components of the end item, which are ultimately assembled into the end product.

The Work Breakdown Structure is the framework for defining the planning networks and points of control for the accomplishment of the project.

Criterion for its construction

The criterion is the integration of the end product, personnel structure, and the accounting system into an operating entity. Milestones and interfaces are identified for the control

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Network-Based Management Systems (PERT/CPM) (New York: John Wiley & Sons, Inc., 1967), pp. 28-40. (Hereinafter referred to as Archibald and Villoria, Management Systems.)

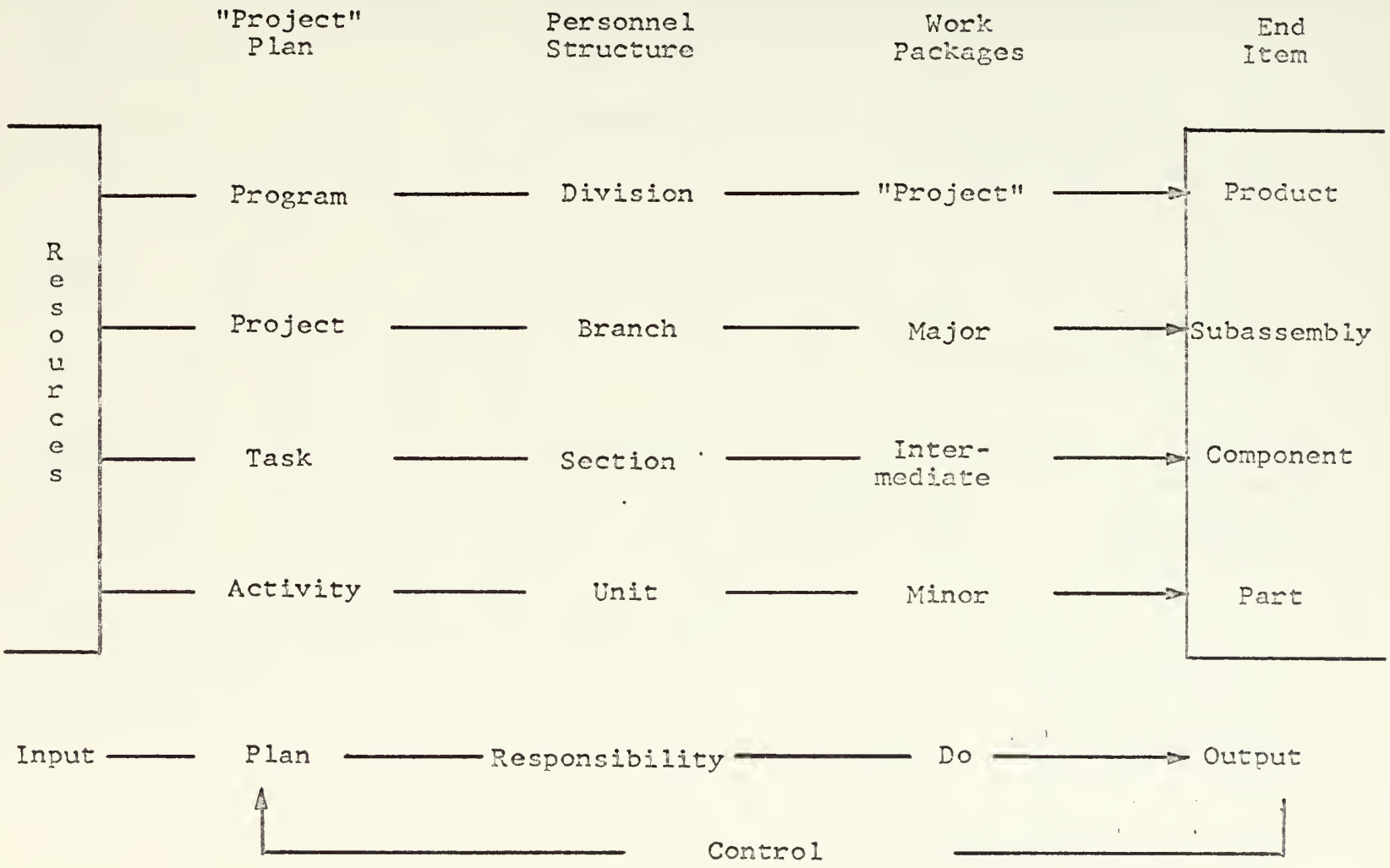

Fig. 2.--Project Flow

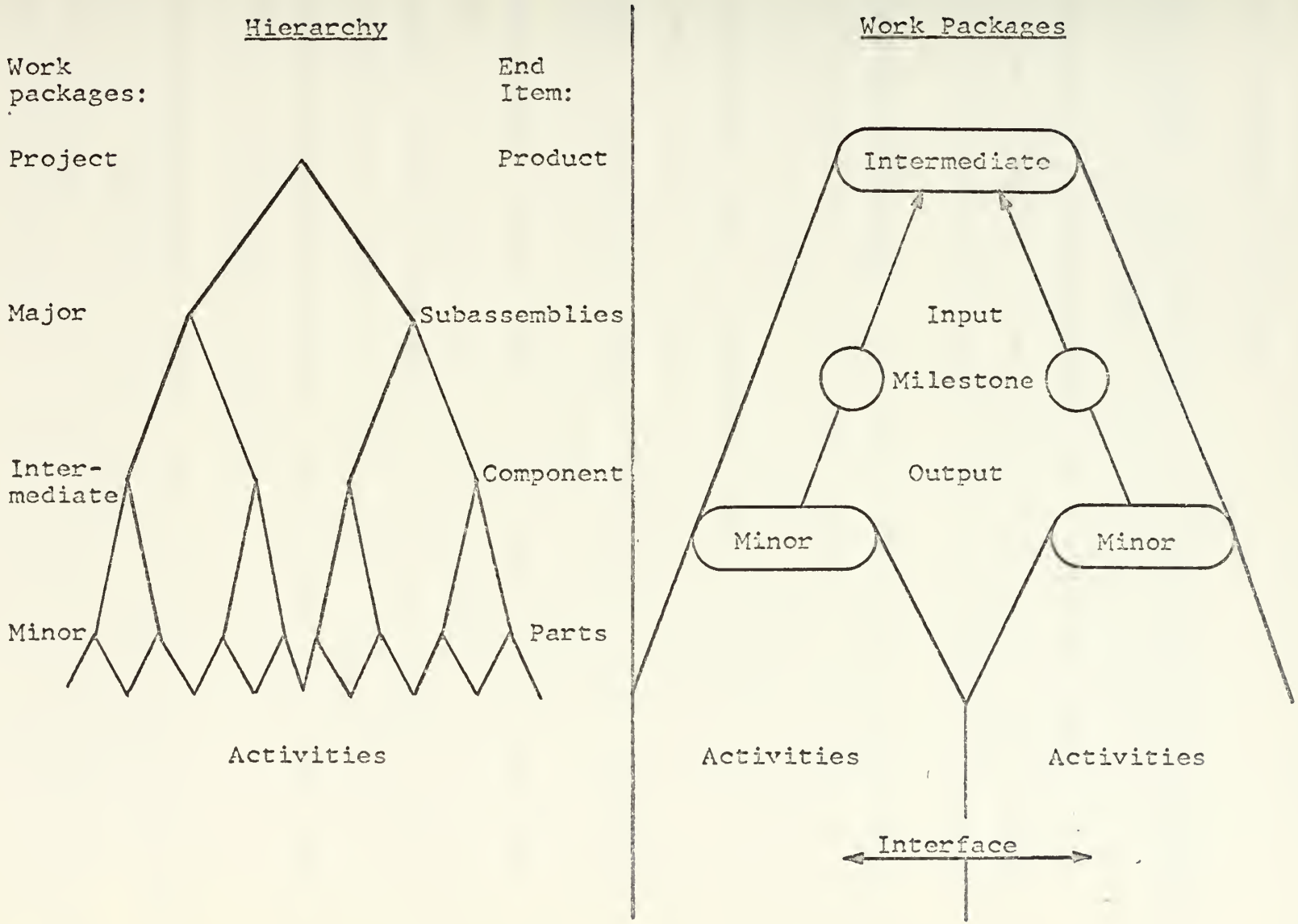

Fig. 3.--Work Breakdown Structure

and co-ordination of the project. Networks are applied to the Work Breakdown Structure.

End product.--The end item is the tree upon which everything else is hung. The end item is what must be accomplished and everything else is subordinated to it. The first step is to completely define the end item and break it down hierarchically into its subordinate parts, down to the lowest supervisor.

Personnel structure.--The proper correlation of the personnel organization with the end item hierarchy is the key to effective planning and control of the project. Each unit of the personnel organization must be responsible for a specific part of the end item or a specific supporting product leading to its accomplishment. The personnel organization and end item hierarchies should coincide as closely as possible. If necessary, the personnel organization should change to fit the end item breakdown. If this is not possible, the end item breakdown structure can be further refined by dividing its parts into smaller entities to accommodate the personnel organization. The goal here is to see that two different personnel units do not have joint responsibility for the same end item part.

Supporting products.--These items are added to the Work Breakdown Structure in the appropriate places, as they effect the accomplishment of the end item. They are also correlated with the personnel structure. This would include things that are

required for the execution process but are not part of the end item. Examples would be a temporary building to house a production crew, resource acquisition, or administration and training results.

Accounting system.--In most companies, the existing accounting system is co-ordinated with the existing personnel structure. Certain managers have accounting responsibility and there is a hierarchy of units under them for which accounting information is accumulated. By matching the personnel organization with specific items and services, budgeting and accounting data, based on the end item, can be readily gathered from and assigned to the responsible manager.

Milestones and interfaces.--These are specific, measurable, and sensitive points in the Work Breakdown Structure at which planning and control action can be taken by project managers.

Milestones are the subordinate objectives of the project which measure progress. Normally most parts of the end item hierarchy should be considered because they provide a positive measure of progress on the project. Key supporting items may also be designated a milestone because of their importance to the project.

Interfaces are those points where responsibility passes from one unit to another. This could be a point such as a supply unit passing material to a production unit, at a specified point in time. It could also be the point at which one part of the end

item is completed and passed on to another unit for further assembly into components.

Milestones measure project accomplishment while interfaces measure co-operation and co-ordination. There may be several milestones within a given unit's area of responsibility to measure project accomplishment.

Networks.--A project is made up of many individual networks tied together at their interface points. Conceivably each activity of each individual that works on the project could be networked. But, this would give too much detail, and be impossible to manage. Networks should be started at the lowest personnel unit level, planning the activities of a group of people. More detail of individual operations can be included as needed for the proper planning and control of the activity.

Activities in the project can be completely tied together by their interface events; however, a network for a given level would probably be summarized down to an event representing the multiple activity network for one unit, plus the interface points. The networks of the higher echelons of the project hierarchy summarize those activities under them. For example, a branch's network may summarize all work done on a specific assembly by one event, even though the subordinate networks may contain a thousand different operations. The milestones and interfaces will relate to the assembly process and, in fact, summarize all of the lower milestones and interfaces.

Any given echelon will keep detailed networks of its own activities, but will include only summary events and key milestones and interfaces of the next lower echelon for co-ordination and control purposes. It will also contain the interface events that tie it to the next higher echelon, to insure proper co-ordination and control.

The network for top management will consist only of the major work packages, intermediate milestones, and significant interfaces. Each network should include only those things that the particular manager needs to know to plan and control his activities.

Definition Of and Criteria For the Construction of Work Packages

Definition.--A work package is a group of activities. In any project involving more than just a few people on a simple job, it would be nearly impossible to try to keep up with all of the individual activities that might take place. The individual manager wouldn't have the time to set up the PERT COST model to analyze the project because of the clerical load. To solve this problem of detail, activities may be grouped into work packages.

Work packages form a hierarchical organization which is overlaid on the Work Breakdown Structure. There may be several work packages on any given level or in any given vertical chain of command. Work packages at a lower level will be contained in the larger work packages of the next higher level. For example,

one work package may contain several subordinate work packages. A work package normally will not cross the chains of command, that is one manager equals one work package.

Criteria.--A work package should be designed around the milestone structure, the accounting system, and the management responsibility pattern.

Work packages should culminate in one specific milestone. The final milestone of the package should be easily measured and related to the progress of the project, such as providing thirty-two trained personnel, forty tons of sand, or an operating cafeteria.

The general concept of a work package is that it is the unit for the project cost accounting.[1] There are too many individual activities to keep up with to make cost accounting for each activity practical. This much detail is not good for management, as it cannot be readily digested. If the Work Breakdown Structure has been correlated with the accounting system, it should be an easy matter to correlate the accounting system with the work package structure. This correlation will provide budget and cost data on discreet, measurable parts of the project to aid managers in planning and controlling the operations of the project.

The work packages are also correlated with the personnel structure and management responsibility. The manager should have full control of his resources and objectives. If two managers are working toward the same goal, any problems are always

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[1]Archibald and Villoria, Management Systems, p. 37.

caused by the "other guy". The individual work package gives the manager an identifiable and measurable part of the project to accomplish, the necessary resources, and the responsibility for its accomplishment.

Summary

The Work Breakdown Structure defines the hierarchical organization of the project, assisting the manager in organizing, networking, optimizing, and reporting on the project.

The following criteria apply to its construction. The end product is the tree with which the personnel structure, supporting items, and the accounting system are correlated. Milestones measure specific accomplishments in the progress of the project. Interfaces identify points where managerial responsibility changes hands, requiring co-ordination and control by higher management. Networks are formed at the lowest supervisory level in detail and passed upward in summary form. All networks are tied together at their interface points and their progress measured by the milestones accomplished.

Work packages are groups of activities that give a manager an identifiable and measurable part of the project to accomplish, the control of his funds, and the responsibility for accomplishment.

How Can the Individual Manager Acquire the Cost Data

The individual manager is handicapped in acquiring cost

data. There will not be formal recognition of his requirement or desire for new cost data. The cost data that is available will not be PERT oriented. In addition, there will be resistance from subordinates and other managers to making any change in the type or amount of the cost data currently available.

The purpose of this section is to discuss the methods whereby the manager can acquire the cost data he needs. Two basic ideas will outline the procedure.

1. Availability of cost data.
2. Developing more cost data.

Availability of cost data

The manager must clearly define his present status in terms of what cost data is currently, readily available, what can be easily obtained, and what the attitudes and skills are of those providing the cost data.

Readily available.--The manager should start his PERT COST practice models with whatever cost data is available. To start with, any reasonably accurate data will do. Use it as the "normal" cost figure in the model. There will probably be some information at hand on direct and penalty costs, but little on indirect and nondirect costs. Some leading questions, such as, which alternative costs more or how much a specific activity costs, amy elicit more cost data.

Easily obtainable.--Discover what costs are easily obtainable at

this stage of the game. There will be other cost planning data that can be used, such as budget planning data on labor rates, production rates, or indirect expenses. Some additional cost data can be derived from the existing data base with a little planning and training. The "state of the art" of the accounting system is a serious limiting factor on the availability of cost data. Subordinates can't give cost data they can't get.

Attitudes and skills of others.--The attitudes and skills of those who will supply cost data to the manager are the key to his success. The manager will be ahead of his subordinates and other managers in cost emphasis and project analysis ability. If he antagonizes the, they will resist him. He must bring them along the same road that he is going down, keeping their attitudes favorable and developing their skills slowly, giving them a feeling of accomplishment and greater importance.

Developing more cost data

The PERT COST model can be used to identify specific problems that will emphasize the need for more cost information and its use in planning and controlling activities and projects. Along with this, organizational measures of effectiveness, efficiency, and economy should be developed to use as a standard against which to compare project performance.

PERT COST model.--The manager should plug whatever data is available into the PERT COST model. This will do two important

things for him. First, it will show where the gaps in the data are and pinpoint questions for discussion with others. Second, the data may be complete enough to identify major problem areas and the facts and figures that effect them, which again can be referred back to subordinates and associates for further problem solving.

Emphasize need.--A change in the level of available cost data will be achieved easier if a dramatic need can be demonstrated. The questions and the major problems identified by the PERT COST model can supply this need. If they are presented in everyday language and common sense, the problems can be explained along with the magnitude of their effect on the project completion time and cost.

In a group discussion, the manager should identify and rank the questions and problems according to their effect on the project completion time and cost. The most important ones should be considered first. In the beginning, probably only one or two will be adequately solved, so they should be the most important ones.

During the discussion, the manager should develop the ability of his people to see the variables, the controlling factors, and the need for more cost data and better analysis. The relationship of the variables of performance, time, cost, resource trade-offs, and time-cost trade-offs can be brought out by skillful questioning. The controlling factor of minimizing total cost can be given strong consideration in evaluating

alternatives. The use of this approach should clearly show the need for more cost data, thereby, motivating the subordinates to try to come up with it; so, the current problems can be solved.

As subordinates become comfortable with this procedure, the manager can introduce some PERT jargon and analysis procedures to further refine the discussions. As PERT is brought into the discussion more and more, the others will start using it and developing their own cost data, which is what the manager wants. In time, everyone should be going down the same road.

Organizational measures.--Concurrently the manager should be developing organizational measures of effectiveness, efficiency, and economy to foster cost consciousness at the organizational level vice just projects. This will also put the project interest into the proper perspective and justify interest in it.

Effectiveness should be explicitly defined in terms of what must be done and how well. All activities should contribute positively to the accomplishment of this goal or be dropped.

Efficiency is the amount of input versus the amount of output. Definitive measures of the input of all resources should be developed so that the number of units of each can be counted. Likewise, a discreet measure of the output must be developed so that individual units of output can be identified and counted. After this, productivity indices can be set up to measure the efficiency of the organization for various resources such as manhours, materials, equipment, and facilities required per unit

of output.

Economy is the cost per unit of output index. This is the common denominator of the productivity indices. The productivity indices should be varied, in order to reduce the economy index.

These organizational measures will show subordinates where they stand now and challenge them to improve. The PERT discussions will show them how to develop these changes. The goal of the activities, projects, and changes, is to improve the organizational performance measures.

Summary

The individual manager can acquire cost data by using what is readily available, by training his subordinates to derive new cost data, and by setting the environment for the production of more cost data.

The current situation will provide some cost data readily. Additional data may be easily obtained from budget planning figures and new derivations from the present data base. Whether the latter source can be effectively tapped or not, depends on the attitudes and skills of the subordinates, other managers, and the "state of the art" of the accounting system.

The manager can use the PERT COST model to identify the questions and problems to use in establishing the need for more cost data. This will also give him a framework within which to train and develop his subordinates in the acquisition and use of more cost data.

The explicit definition of organizational goals and measures of performance will set the organizational environment, a perspective, and a standard of comparison for activities, projects, and proposed changes.

Summary

Costs are integrated into the PERT COST model as the common denominator for all activities, alternatives, and measures of efficiency and economy.

The cost objective is to minimize the total costs for the project. This includes the costs for the project and the costs caused by the project. The absolute limits of the total cost are the least cost point with the maximum time and the least time point with the maximum cost. In between are the practical limits of the normal, crash, and directed time points and their related costs. The PERT COST model will minimize the total costs for any of the above time constraints. The cost mix is optimized by buying time with direct costs in order to reduce the variable nondirect and penalty costs.

The cost objective is reached by job costing and by budgeting each activity for three time variables: normal, crash, and directed. Initially, normal and crash times and costs are sent from the bottom to the top of the project, to give the practical time and cost limits of the project. If the normal limit takes too long, the time is reduced by buying time along the critical path, until the directed time is reached and the total costs are

optimized for that time. The directed time and cost figures are passed down the project to the lowest activity for readjustment and activity optimization.

The Work Breakdown Structure is the hierarchical organization of the project and assists the manager in organizing, networking, optimizing, and reporting on the project. The end item is the independent variable, the personnel structure, supporting products, and accounting system are correlated with it. The resulting milestones are grouped into work packages culminating in one final milestone that gives the manager an objective, control of resources, and responsibility for accomplishment.

The individual manager can acquire cost data by using what is readily available, by discovering what additional data is easily obtainable, by training his subordinates, and by structuring the situation to produce more cost data.

CHAPTER III

HOW CAN THE INDIVIDUAL MANAGER PLAN WITH PERT COST

PERT COST is primarily a management tool for planning. Secondarily, it is a system of control, as such, PERT COST can be a very complicated system and may develop a large volume of computational and clerical work.

The purpose of this chapter is to show the individual manager how to use PERT COST for planning while minimizing the computational and clerical work.

The main ideas to be presented are:

1. What is involved in PERT COST planning?
2. How much should the manager do?
3. How much should subordinates do?

What Is Involved In PERT COST Planning

Total process

The total PERT COST planning process is portrayed in Appendix B through J.[1]

The flow charts are developed down to the major work

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[1] These flow charts are a synthesis of the PERT COST planning procedures presented in the Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, pp. 23-51 and in Archibald and Villoria, Management Systems, pp. 23-45.

packages and intermediate milestones. In some areas more detail is offered to clarify relationships or procedures.[1]

These flow charts are designed to bring together into one comprehensive procedure, the steps of the PERT COST planning process in a form that can be used by the individual manager.

The probability feature of PERT COST is not considered because it would probably be of little use to the individual manager. It is clearly explained in most PERT COST references.

Concurrency of time, resource, and cost analysis

Interdependent variables.--The three variables are interdependent and must be handled as a package. Any change in one effects the other two which in turn may effect the changing of the initial one.

Time.--Time is dependent upon the resources available, which, in turn, are dependent upon the funds allocated to the project. The normal-crash time points may be on a continuum or they may be discreet. For example, normal time may be figured on a single shift. There may be no way to crash this time except by adding a second shift which will double the output. No output between single and double is efficiently available; hence, the two points are discreet. The choice is 'either-or' not somewhere in between. The use of overtime may allow output between the single and double levels making a continuum between the normal and crash points, or providing additional feasible points.

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[1] Horowitz, Critical Path Scheduling, gives an excellent, simplified approach for handling the mechanics and detailed clerical work of the plan.

If there are not enough personnel available for a second shift, the crash point will be below the double level. If additional funds are not available to pay personnel overtime or double shifts, the output will be limited to the normal level of the single shift, and the normal and crash points will coincide.

Resources.--The type and quantity of resources used are similarly determined and are based on the adequacy of time and funds. The cheapest resource for the time available should be chosen. The scarcity of resources may not affect their cost but may affect the scheduling of the activity in an adverse manner. Any change in the resource level will affect the time and cost of the activity. If the money is limited, the time may have to be extended.

Costs.--Costs are directly dependent upon the resources used in the activity. If time is decreased, the cost will generally increase because it will take more or better resources to accomplish the job in less time. The converse applies in lowering the cost of an activity. If funds are scarce, it may be impossible to reduce the time because additional resources cannot be purchased.

Work packages.--This interdependency of time, resources, and cost applies to work packages as well as individual activities. These variables must be suboptimized for each work package starting from the lowest and working up to the total project. Resources

adequate for one activity may not be able to handle other activities concurrently. For example, one steam shovel can dig only one hole at a time. The result may be a serious delay in the project, due to scheduling a limited resource sequentially. This delay may be offset by juggling slack activities, substituting other resources, or by buying additional resources.

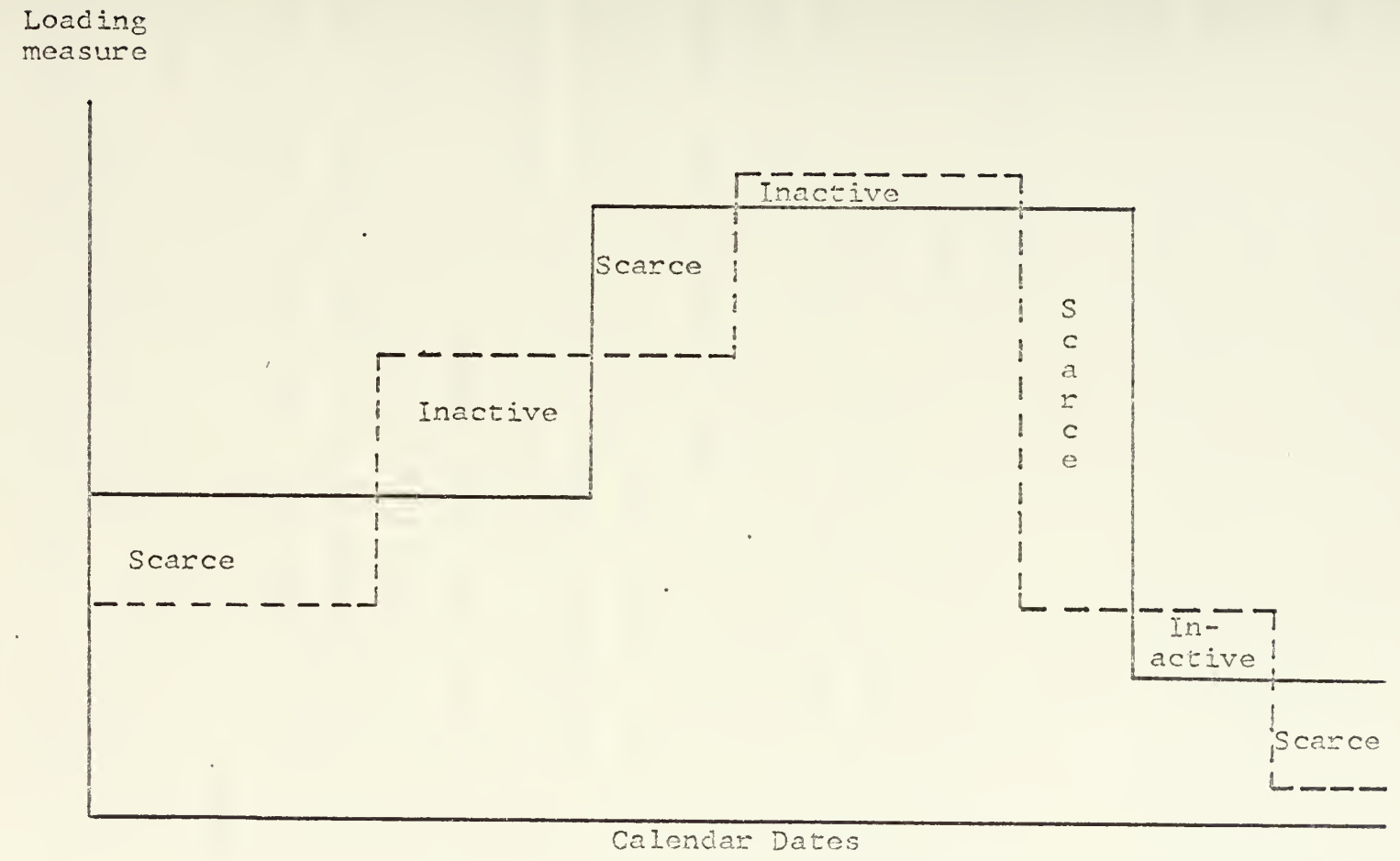
Resource leveling

Critical and inactive.--The key considerations in using resources is to have them when needed and to avoid costly, inactive resources, when they are not needed. Idle equipment and personnel add to the overhead costs of the project. A shortage of equipment or personnel will likely delay the project and increase its cost.

Analysis.--Detailed availability or inactivity analysis should be limited to those resources that are likely to become critical or inactive. Figure 4 is a resource loading and leveling graphic technique that can readily identify scarcity and inactivity.

Both problems can be minimized by juggling slack path activities to improve resource scheduling. Past this point, scarcity can be reduced by extending the project time. Inactivity can be decreased by reducing the time and utilizing more resources.

Costs.--Costs can be significantly affected by this analysis. Inactivity costs money and may mean that resources can be



Available Resources — — — Required Resources ————————

Source: Adapted from Horowitz, Critical Path Scheduling, pp. 84-103.

Fig. 4.--Resource Loading and Leveling Analysis

disposed of, and money saved. By reducing peak loads (leveling), the level of resources may be reduced and more effectively utilized because inactivity will not have to be tolerated in order to avoid scarcity during peak useage. In addition, with this graphic technique, the period of scarcity can be readily indentified and resources acquired only for that need. By not holding the resource prior to the need or after, its total cost can be reduced.

Cost account codes

This subject will not be handled in this paper. If the individual manager is working with a sophisticated, project cost system, he may already be on a formal PERT COST system. The average manager will probably have little, if any, signs of an adequate cost analysis system. There may be a basic accounting system oriented toward total unit costs. The average manager will not be in a project oriented organization. His projects are important but not usually large enough to warrant any additional cost accounting system modification to accept them. The project's envisioned by this paper are such things as: annual inventory, requisition reconciliation, moving, establishing a new unit or operation, or analyzing daily operations.

The manager may want to head for a cost system that could include, on an optional basis, the costs for specific projects. This could be easily accomplished in the basic accounting system by extending the unit account codes to accommodate project

entities. This could, also, be done in an extra field or information box. Additional numbers will be required: two for the project, one for the major work packages, one for intermediate work packages, and one for minor work packages, for a total of five extra numbers. After the normal accounting runs, these cards could be selected and used to prepare any desired reports.[1]

Summary

PERT COST planning is a very thorough system. Appendixes B through J give a comprehensive procedural guide for the major parts of the system.

Time, resources, and costs are interdependent at all times and must be analyzed and suboptimized together starting at the lowest activity and working up through the work packages.

Resources must be analyzed if scarcity or inactivity is likely to exist. Figure 4 gives a graphic technique to accomplish this easily. Resource costs may be reduced by properly scheduling and leveling the peak requirements.

Cost account codes may be readily established for work package entities in a normal accounting system as additional digits in the account number or an extra information field. These cards can be selected out and used to prepare management reports as required.

How Much Should the Manager Do

As can be seen in Appendixes B through J, there can be a

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[1]See Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, pp. 7-22, for a variety of cost reports that have already been formulated for use with the PERT COST system.

great deal of detail involved in a complete PERT COST plan. There are limits to how much detail the individual manager can handle and how much detail is of value to him.

The individual manager can afford to spend only a little extra time working on the mechanics of such a system. The PERT COST system will improve his planning and control capabilities, but the amount of time saved can be used for better things than the valueless details of excessive clerical work.

At best, the manager's work environment is one of generalities. Subordinates may only know or only be able to come up with some general cost figures and make broad gauge extimates on others. To become deluged with a myriad of computations, based on general figures and broad estimates, will add nothing to the possible improvements to be achieved through the system.

Guidelines

Implicitly there appear to be three general guidelines the individual manager should follow to maximize his effectiveness while minimizing his additional clerical duties.

Project summary network.--First, the manager should generally confine his computations to the project summary network and the effect of the major work packages on the total project. Anything below this level should be handled by those directly responsible for the work in the best way they can. At this stage, it is not expected that the subordinates will also use the PERT COST system.

Project control network.--Second, the manager can use the information provided by subordinates to construct the project control network. In doing this, three intermediate objectives should be set in each major and intermediate work package. The first provides a check on planning. The second provides a check on operations. The third provides an additional check on operations plus an opportunity to make adjustments to accommodate terminal activities.

Planning group participation.--Third, participation should be the primary method of developing the project plan. Only through the manager's questions and synthesis of available data can he guide his subordinates down the road toward more effective planning. Although the group approach seems slow, everyone will be up on the plan from the beginning and better able to make subsequent decisions. The group approach will also solve most of the co-ordination problems before they occur.

Managerial areas of responsibility

In the following paragraphs, a few comments will be made on the manager's approach to his eight areas of responsibility in planning under this system.

Describe the situation.--The manager should guide the group in a thorough discussion of the goal, resource constraints, and performance measures so everyone will know where the project is headed, what resources are available, and how performance will be

measured. This is the time to identify potential resource or scheduling problems.

Work Breakdown Structure.--This step lays the ground work for the networks and all later phases of the planning. This discussion will identify what has to be done, who is to do it, possible interface points, and intermediate objectives for control purposes. These points must all be included in each subordinate's plans.

Project summary network.--The project summary network is based on the major work packages in the project. This is the time for a review of the organization of the project and the relationship of the events. The results of this network analysis will provide the facts for further discussion.

Project control network.--This is the project summary network expanded to accommodate the intermediate objectives and interfaces. The prior work should be checked for inconsistencies and problems.

Normal-crash optimization.--The subordinates will prepare and submit the normal-crash times, resources, and costs for the major work packages. These figures will probably be only general estimates, but they are a lot better than nothing. The manager will optimize the project summary network based on them. This will give the manager the least cost time as well as the least time limits for the project. It is unlikely that these limits can be changed unless a significant change in resources is made.

Project optimization.--The manager will compare the normal time with the directed time. If the normal time is equal to or less than the directed time, the project is already at its least cost point, so further expansion of time will only increase the direct costs. If the normal time is greater than the directed time, the project time must be reduced along the critical path. This can be done by first eliminating marginal activities, then by increasing the concurrency of activities, by a trade-off of resources between slack activities and critical activities, or by purchasing additional resources. When the adjusted project time equals the directed time, the manager has met the directed time constraint.

The optimization of the variable nondirect and penalty costs is elusive and may take some digging. The accounting system may supply some of the information such as the organizational overhead to be applied to the project. Lost sales or time values can be estimated by those effected by the project. These costs should be presented to the planning group for an attempt at purifying the list and amounts through the personal knowledge of the group. Then the manager should optimize his summary network and present the results to the group with suitable explanations and group discussion on the feasibility of the proposed solution and any suggested improvements. The subordinates will then suboptimize their work packages for these changes. At this point, the subordinates should finalize their work packages and include the details for the intermediate milestones and interfaces.

Fixed nondirect and penalty costs.--Again the costs should be gathered from all available sources and discussed within the planning group. The addition of these costs to the optimized project costs, will give the total cost for the project optimized for the given constraints. This should be a good ball park figure, as it is based on the extimates of experienced subordinates. It is not a figure that can be used at face value though. Actual costs will vary from this figure due to environmental changes, errors in estimating, and the inaccuracy of forecasts. But the variations should be explainable and their discussion used to promote better planning in the future.

Project control network.--This is a group activity with the data being furnished by the group and the network being worked on by the manager. These are their agreed upon figures and should generally be taken at face value unless obvious conflict exists. The control network provides a last chance to discover problems and errors in planning. Any problems should be ironed out on the spot, if possible. When this network is completed, the result will give the controlling points for the manager and the reporting points for the subordinates.

Summary.--The individual manager must limit himself to the project summary network and the project control network in order to minimize his clerical work. All analysis at the project level should be based on data supplied by the project planning group or individual work package managers. The detailed computations and

data within the work packages are developed by the subordinates in their own planning activities within their own organizations.

How Much Should Subordinates Do

The subordinates should be encouraged to do as much as possible on their own work packages and to contribute to the discussion of project-level problems and performance, through questions, reasoning on problems, and the organizational performance measures. The manager must not do their jobs for them or he deprives them of the opportunity to learn.

The accuracy and completeness of data will improve as the subordinates learn the requirements and how to obtain the necessary data. On each project, the manager should attempt to develop a little more data than was available on the last project.

Subordinate's areas of responsibility

The subordinate managers should develop the following four portions of the PERT COST plan in their own way.

Construction of work package networks.--This is the time that the subordinate defines the specific relationship and sequence of activities under his responsibility. Their methods may be intuitive and take the form of a listing or other grouping. The format is unimportant, so long as the final results are understandable. If they aren't, it will come out in the planning group discussions and changes can be made.

Activity normal-crash time, resources, and costs.--The subordinate prepares two alternatives for each activity based on the normal-crash concept. It is important at this point to indicate whether a continuum exists between the normal and crash points. If not, he should indicate other specific feasible points to be used in the optimization processes which will follow.

Suboptimize normal-crash time, resources, and costs.--After the activities are analyzed, the work packages should be suboptimized starting at the lowest and working up. When the manager gets the results of the major work package suboptimization, he should be getting the least cost and least time data for the execution of the entire work package not merely the summation of the individual activities. This will require subordinates to use the concept of critical path and slack activities. It may take the manager some time to develop this capability in his subordinates.

Suboptimization of project time, resources, and cost.--The manager will determine the normal and crash limits of the project, equate the project time to the directed time constraint, optimize the variable nondirect and penalty costs, and derive a minimum total project cost. The revised work package figures will be passed back to the subordinates. At this time, they will finalize their plans and complete the detailed scheduling and costing for the intermediate milestones and interfaces, based on the final time, resource, and cost constraints. They will use these final figures as input to the project control network as a final check for

accuracy and completeness.

Summary.--Subordinates should be guided in developing the plans for their own work packages. Initially, the resulting data will lack accuracy and completeness, but as they get a number of projects behind them, it will improve. They will learn what is expected, why it is important, and how to obtain the information either through their own systems or by imitating the manager in his use of the PERT COST system. How they do it is not as important as whether they can come up with the information.

Summary

The individual manager can use the PERT COST system as a comprehensive tool for the analysis and planning of the interdependent variables of time, resource allocation, and costs. Appendixes B through J give an overview of the entire process.

If the system is carried to its ultimate detail, a mountain of computational and clerical work will result which will be impossible to accomplish manually. The manager will have to confine himself to the project-level phases of the procedure. He will receive input from the subordinates, which they will develop within there own work packages. Even in the work packages, the detail can be staggering. Therefore, emphasis should be placed on using general plans and estimates based on the experience of the subordinates.

The real effectiveness of the system lies in developing subordinates to think in terms of the total planning process, to

recognize the interrelationship of the variables, and to develop methods to solve their own problems. A participative approach will increase the training each subordinate receives and provide an excellent means for increasing the co-operation and co-ordination in the accomplishment of the project.

CHAPTER IV

HOW CAN THE INDIVIDUAL MANAGER CONTROL WITH PERT COST

The process of control must be a continuous process throughout the accomplishment of the project. The execution stage is when the manager and his subordinates find out how effective their plans are. However, if they wait until the end of the project to compare their execution with the plan, it will be too late to take any corrective action. Plans must be changed to meet the changing conditions of the project. To do this, the manager must cause frequent comparisons to be made of what is being done with the current plan. When variances occur, either the operations must change or the plan must change to adapt to the new conditions.

This chapter will discuss procedures by which the individual manager can control the project, through the continued use of the PERT COST model.

To do this, two questions will be considered:

1. What effects the control situation?
2. What are the control procedures?

What Effects the Control Situation

There are three factors that effect the control situation: (1) the manager, (2) the subordinates, and (3) the organization. Each factor places constraints upon the situation that effect the actions of the manager. He must take these constraints into consideration when he decides on his control procedures.

Situation

Manager.--The manager is the protagonist in the situation. He has started using a new management tool that he thinks is great. He understands its use and capability. His motivation to expand its use and effectiveness is high.

Through his initiative, the emphasis on cost effectiveness and planning has taken a new look. This procedure has been tactfully forced upon his subordinates, and the quality of their response has effected his feelings toward them and their abilities.

Subordinates.--The subordinates resist the manager and his planning "games". He has disrupted their normal way of doing things. The work has always gotten done before and all this playing with figures isn't going to change that. Additionally, the boss has a specific standard to compare them against. If they don't do well, they will look bad and their promotions will be effected. They have a tremendous job just keeping up with all of the paper work that is required now. This additional clerical

load is too much. Besides they don't have the means to keep up with all of the cost and time figures.

Organization.--The organization hasn't changed to accommodate these new procedures. Their are no new cost accounting aids to the manager or subordinates to help plan, collect, and analyze the cost data on the project. There are no computers to ease the clerical load on all concerned.

The subordinates have been in their jobs for some years. The manager is new and he will probably only be there two or three years. No matter what he does, the next manager will not follow-up on it, especially something as fancy as this. If the subordinates humor him, he'll go away in a year or so, and they can go back to the old ways. If he gets to fanatic, they can get him transferred.

Approach

The manager must set up some general guidelines, based on the above constraints, for his control procedures. The following five points can give the manager a start on this task.

Goal.--The manager's goal is one of evolutionary improvement, not revolutionary chaos. The project is likely to get done whether he uses his system or not. The manager is only trying to get the project done a little better. Any improvement is a sign of progress. The manager must move slowly or he will leave people behind, that have not understood what is happening, and

antagonize the rebellious personalities. The result may be that the project won't get done at all, because of the confusion and political unrest. Slow but steady is the only proper course of action. "Rock the boat" just a little.

Group participation.--This is the most effective and efficient approach for the manager. This allows the manager to train everyone at once, and for everyone to benefit from the questions and experience of the others. The ones who grasp the procedure and what the manager is trying to do will have an audience for their ability. Those who don't grasp the situation will have someone else to turn to for help besides the manager.

If the manager can get the group, as a whole, going down the right road, social pressure will pull the dissenters along. This social pressure will also be applied during the group activities to those that are lagging in participation and information. The adverse effect of one subordinate's actions will be brought out by the other subordinates that are effected.

Minimize clerical work.--The worst part of any operation is the clerical work involved. Reports are frequently an inefficient activity. The manager should take maximum advantage of "fill in the blanks" type of reports, to minimize repetitive typing operations. Other time savers are the photocopier and continuous graphs or charts.

A graph is easily maintained and easily photocopied. After the current information is added, it can be copied and a few

remarks attached and passed up as a report. It has the additional advantage of giving the past history and trend of the information.

Discussion type information can be handled orally and action taken immediately. If a record is required, the discussion can be summarized and action noted.

Minimize details.--Details will add an inordinate amount of additional work to the subordinate's work load. If general totals and estimations can be used, the additional work can be minimized.

The plans were based on estimates and round figures so little will be gained by refining the details at this stage of the game. If the subordinates can keep up with the total figures for the major and intermediate milestones, the manager can consider himself lucky.

Emphasize project totals.--There are two reasons this is important. First, the system can put individuals on the spot quickly because errors are readily identified. If an individual is embarrassed too often by the system, he will avoid it at every chance and try to get others to do likewise. It will take time for them to fit themselves to the system and accept it as a challenge and worthwhile measure of their performance. Second, cooperation will be enhanced by striving toward a common goal. If everyone is trying to look better than his associates, co-operation and co-ordination will be minimized. This will not only cause problems but hide ones that could have been solved

easily. The good subordinates will withhold their knowledge and support from those that need help, so they can look better. The project totals can only be reached through a team effort. Anyone not pulling his weight will soon be recognized.

Summary

The situation effects the manager's approach to setting the policies for the control procedures.

The manager, subordinates, and organization all bring constraints to bear upon the effectiveness of the control procedures. The manager is the protagonist, pushing for the use of the PERT COST system, while the subordinates and the organization are resisting its use because of the additional work load on them and the newness of the ideas.

The manager must take a soft approach with an immediate goal of improvement, however slight, not revolutionary change. He should use group participation to increase the effectiveness and efficiency of his training efforts and to get the support of his subordinates. Minimization of the clerical work and details involved will reduce the resistence to change. Co-operation and co-ordination can be improved by emphasizing the project totals rather than individual performance.

What Are the Control Procedures

The control procedures are so important to the accomplishment of the plan, that they should be a separate planning operation. During the project planning stage the project control

network is developed to give a control standard. The second step should be to determine how this network will be used in controlling the execution of the project. It will be impossible to control everything that happens explicitly; so, a few sensitive factors should be monitored to give an indication of problems that require more intensive investigation. Some basic questions that will orient the control planning must be answered:

1. What progress has been made toward the project goal?
2. How fast are the scarce resources--time, resources, and money--being consumed?
3. Will the project objective be met?

The planning group should develop the information it needs to control the project and report progress to higher authority. If everyone is involved, a reasonable degree of control and associated additional work load can be established that will be acceptable to all. An attempt should be made to give the planning group the feeling that they are controlling themselves, which they should be. The more the manager can encourage this feeling, the better will be the self-control of each of the members.

This section will discuss five phases of the control cycle:[1]

1. Approval power
2. Collection of "actual" data
3. Project status
4. Reports

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[1]These five areas are an adaptation of the control procedures presented by the Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, pp. 23-5, and Archibald and Villoria, Management Systems, pp. 142-4.

5. Follow-up action

Approval power

Control starts at the beginning.--Approval of the original idea is the point at which the manager starts his control process. There are more good ideas than the organization can act upon at one time. The manager must be careful to approve only those ideas, and in priority, that will have a beneficial effect upon the organizational performance measures.

By selecting the ideas that will improve the performance measures the most, the manager will be able to show tangible evidence of his improvements, the subordinates will recognize the improvement and be motivated by the success, and working conditions should improve for all, giving a lift to the overall morale and respect for the manager.

If other ideas are allowed to be developed, they will conceal the really important ones, use up resources that could be better used elsewhere, have little or no effect on the performance of the organization, and will add to the work load of the employees instead of improving it; all of which will be detrimental to the organization.

Feasibility study.--Even the careful selection and ranking of ideas as to their effect on the organizational performance measures does not give a complete picture of their value to the manager. The organization only has time to work on one or two

extra projects along with its normal activities. If the employees can see some personal benefit coming from the time spent, they will support the project. Smaller projects provide a better training activity because the whole thing is visible; however, if they are too small, a formal planning procedure uses up too much time and adversely effects the performance measures.

All ideas should be subjected to some kind of feasibility study. If everyone is familiar with the situation, a group discussion can serve this purpose. All of the ideas must be evaluated for the following factors:

1. How much effect will the idea have on the organizational performance measures?
2. Can it be accomplished by the organization?
3. By what alternative methods can the idea be accomplished? Which method is best?
4. What will the time and cost in resources be for the idea? What will the performance measures for the project be?
5. Is the accomplishment simple or complex?
6. How long will it take to recover the project costs?
7. What is the likelyhood of success?

At this point, the manager should apply three additional criteria to the selection of specific projects. First, probably only two projects should be selected. One should be a short run effort; the other one can be a medium to long range effort. Second, those projects that give the greatest return for the effort are preferred. Third, employee desires must be a strong

consideration. If they are interested in the project, they will have that much more motivation to see that it gets accomplished.

Guiding the planning effort.--As discussed in earlier chapters, the manager must now assume the role of coach in the planning effort. In this manner, he can guide the discussion and planning to insure that the important problem areas are covered and planned for. Through his guidance of the discussions and use of the blackboard, he can easily interject the basic PERT COST concepts.

Authorizing the work.--The manager has final veto power over the project plan. Therefore, the subordinates will try to please him, but if he makes it too difficult to please him, they will give up. He must reach a balance between perfection and practicality. As explained earlier, any improvement should be accepted and the approval given. With practice the employees will gain effectiveness.

Summary.--The manager's approval power is an accepted influence on the subordinates. For maximum control he should use this power to select those ideas that are most beneficial to the organization, as a whole, to cause a feasibility study to be conducted, and to approve only those ideas that will improve the organizational performance measures the most for the least cost, consistent with the desires and workload of the employees.

Collection of "actual" data

During the execution of the project, the actual time, resource, and cost data must be collected to compare against the plan. In a formal, computerized system this data would be the natural outgrowth of various scheduling, cost accounting, and reporting systems. Here the subordinates do not have those facilities or the time to substitute informal record keeping.

Plan equals standard.--There is no need to keep separate records as long as the plan is working. In developing the work packages, the subordinates had to consider what resources would be used and for how long. In the actual accomplishment of the project, the subordinates will attempt to use these same figures. Remarks and completions can be readily annotated on the plan itself.

Changes to the plan.--There are two kinds of changes that must be considered. First, what has been done? Second, what changes will have to be made in accomplishing uncompleted activities?

The plan should show what milestones and activities have been accomplished and what was required to accomplish them, if different than the plan. This becomes the progress record for the subordinate's work package and later for the project.

As the project progresses and the subordinates get more familiar with the activities, they will be able to project changes for their activities. These changes should be frequently reevaluated and kept up to date.

By only recording changes to the current plan, a significant

amount of clerical work can be avoided without losing the major benefits of the system.

Project status

The manager should have reoccuring meetings to evaluate the current project status and the effect of changes. The subordinates collect the actual time, resource, and cost changes to the current plan. This data needs to be reviewed in terms of its effect on the total plan. An optimizing effort in one work package may be detrimental to another work package and the net change adversely effect the project completion time and cost.

Group participation.--The group provides some social control over the subordinates. Any errors or adverse decisions will be quickly noted by others when they effect their operations.

The group can also become a source of information and advice to subordinates having problems internal to their work package. Frequently other subordinates have had the same job and have already solved the problem before. Others have experience in many areas that can be brought to bear.

Evaluate control network.--This is the key to determining the project status. The manager will probably be maintaining the data on the control network by virtue of his superior knowledge of the PERT COST system. He will use the network to guide the discussion.

The Control network is used to keep track of completions.

This can be indicated by a vertical line running through the network and dated. It can also intersect unfinished activities at their approximate point of completion; for example, half done. Putting the control network onto a horizontal time scale can greatly simplify this procedure as well as readily identify those activities that are behind schedule.[1]

Any changes to the planned figures should be annotated on the control network. These figures will indicate variances between the plan and what was actually required. These variances may be of value in forecasting requirements for other activities that have not been completed. Known changes in uncompleted activities should also be noted. These will require discussion and reoptimization of the remaining activities.

The control network will become the diary for the project. Although it can be messy, if too many changes are made, new data should be added, not substituted for old data. That is, line out old and write in the new. The manager can use this data to evaluate variances, subordinate performance and problems, and as a reference for future changes to decide whether the new change is an improvement or not.

Once the new data is annotated on the existing network, the network should be analyzed for the new critical path and the slack activities redetermined. The new, optimized project completion time and cost should be determined.

New problems should be pinpointed for further discussion:

1. Can the project be finished on time?

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[1]For examples of this technique see Archibald and Villoria, Management Systems, pp. 252-3; Miller, Schedule Cost, and Profit Control, p. 79; and Horowitz, Critical Path Scheduling, p. 73.

2. Can the project cost goal be met?
3. What is the current optimum cost?
4. What new scheduling problems are there?
5. What new resource problems are there?
6. What new money problems are there?

Decide on courses of action.--The manager desires to stay within the orginial project time and cost estimations and to improve on them, if possible. He definitely must stay within whatever resource constraints that exist, such as deadlines, scarce resources, pressure of other projects for resources, and budgetary limits.

There are three courses of action that may be considered:[1]

First, to reduce time, the critical path must be shortened. This can be done by making some of its activities concurrent or partially overlapping. The activities may be speeded up by taking resources from slack activities and applying them to the critical path. Some activities might be eliminated or only the essentials retained but combined with another activity. Additional resources can be brought in from the outside at additional cost.

Reassignment of activities from one subordinate to another can be done to ease the work load and to take advantage of additional resources. This will require some adjustment of the work packages.

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[1]Office of the Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, pp. 56-7.

Second, to reduce the load on scarce resources, peak loads must be reduced. The time for the slack activities can be extended. Other substitute resources can be employed, although not as efficiently. Slack activities can be delayed as long as possible, to extend the time that the resource is available for critical activities.

Third, to reduce the cost, the resource level must be reduced. Cheaper resources can be substituted on the slack activities to take advantage of the extra time available. The level of inactive resources can be reduced by proper scheduling or substitutions. Extra resources should be dropped.

In practice, all of these alternatives will probably have to be used to solve the problems. The recognition and application of these alternatives is good training for the subordinates. The better they can make these analyses, the less the manager will have to do for them, and the better they will do their jobs to start with, reducing the crisis situations.

Revise the plan.--When the new plan has been solidified, make the necessary changes to the control network to make it coincide with the decisions. Update the project summary network as required to keep it in consonance with the control network.

Be sure that everyone is on the same track by summarizing all the changes in a memo or copy of the control network for each subordinate. Many changes and ideas will be discussed during the project status update. It would really throw a kink into the

plan if a subordinate picked up the wrong information.

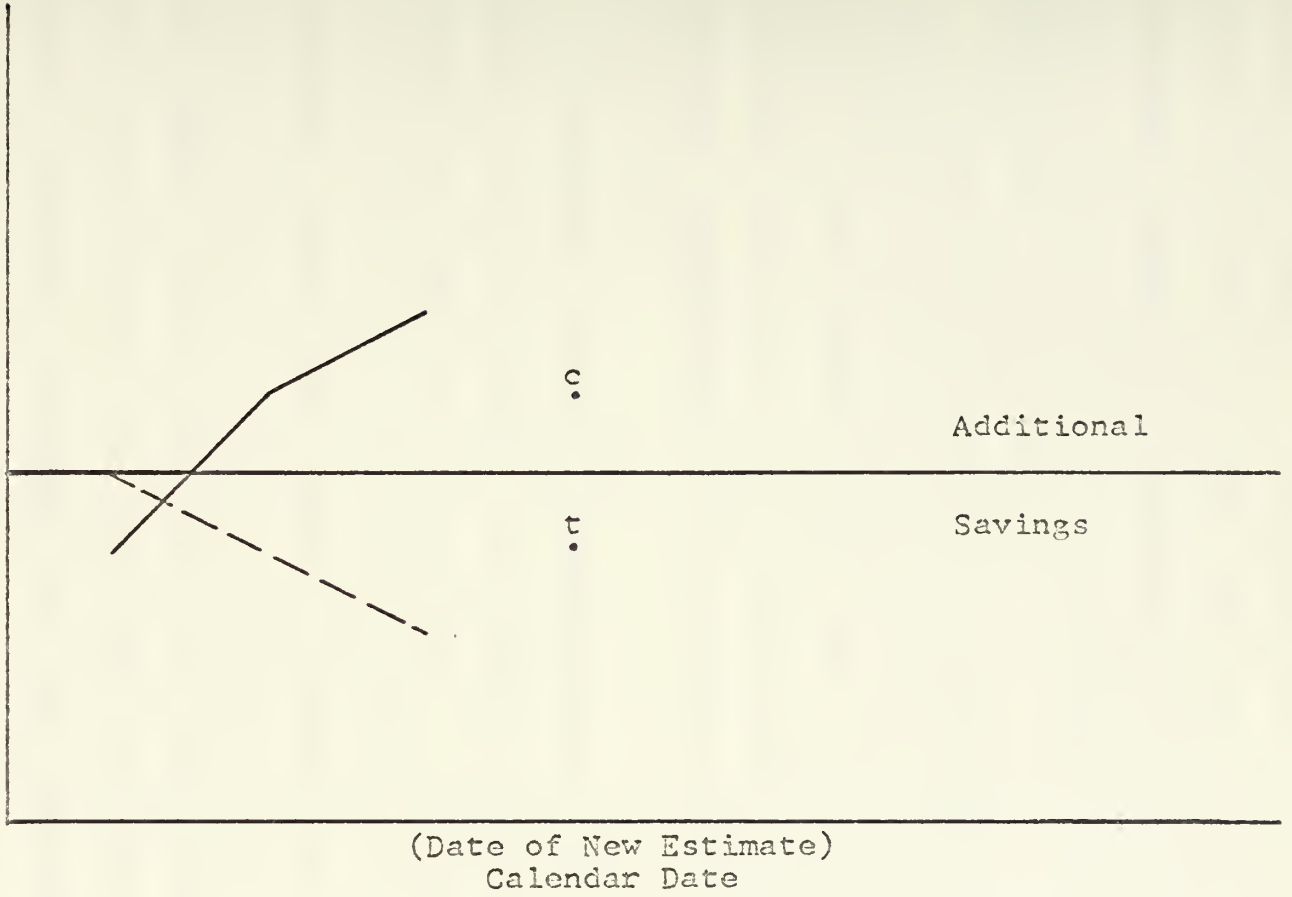
Summary.--The project status should be periodically reviewed by the planning group. The control network should be brought up to date and new information on completed and uncompleted activities annotated on it. The existing network must then be completely optimized again to arrive at the new project time and cost totals. There are many actions that can be taken to reduce time, resources, and cost to stay within the original estimates. These should be considered by the group and a new plan established.

Reports

The report system should be kept very simple and should supplement the work done on the control network, not substitute for it. The detailed changes to the network are handled in the group discussion. This will be more complete and dependable than the data presented in a formal report. The group discussion eliminates the clerical operations in producing a formal report plus it gives more detail which is validated immediately by other members of the group. It would be of value for the group to summarize the pertinent points in a record of the meeting and pass it out to everyone for reference.

Results oriented.--The manager and higher authority are interested in whether the project is going to get done on time and at the planned cost. Figure 5 gives a suggested report to fill this requirement. It shows the actual cost and time

Project Completion		% Var.
Cost	Time	
120	8 Mar.	20
115	6 Mar.	15
110	4 Mar.	10
105	3 Mar.	5
100	1 Mar.	0
95	26 Feb.	5
90	24 Feb.	10
85	22 Feb.	15
80	20 Feb.	20



Cost: Trend ——————
Projected C

Time: Trend - - - - - -
Projected T

Source: Adapted from the Office of Secretary of Defense and National Aeronautics and Space Administration, DOD and NASA Guide, p. 18.

Fig. 5.--Project Cost and Time Trend Report

variation to date and the projected cost and time variation for the next period of operation. By using this kind of report, management can see the results of activities, plan activities to cause a specific change in the variations, and monitor the effectiveness of their action.

The next thing the manager is interested in is how well his subordinates are doing and how effective their actions are. He can use the same format for the major work packages. This not only gives him control of his subordinates but provides additional information as to the causes for any changes in the project status.

This report should be accompanied by a continuous listing of reasons for the variances. For example, after the first period of operation there will be a variance. The major reasons for the variance could be put on a separate sheet at that date. The corrective action taken should be indicated and the projected effect of this action noted on the graph as the target for the next period of operation. After the second period, the same process is repeated on the same graph and remarks sheet. As the project progresses the manager and each subordinate have a good record of their effectiveness and problems.

Clerical work.--The value of this system is that each subordinate and the manager can easily keep up with it, the remarks and corrective action can come from the group discussion, and it takes little or no clerical activity to submit it to the manager

or higher authority. The submission process would be simply to photocopy the graph and the remarks pages and attach them to a letter of transmittal, if required.

Follow-up action

With the manager's approval of the revised plan, the control cycle repeats itself until the project is completed. However, the manager still has some homework to do and management action to take.

Management problem areas.--The PERT COST system is now functioning in some form. Some of its benefits are being realized. One benefit in particular is the identification of problems. The manager probably has more problems now than he knows what to do with.

The group planning sessions have shown the manager which of his subordinates understand and can handle the system. The ones that can't are problems for the manager. The manager should try to determine the specific problem and plan corrective management action. In some cases, the solution may be time and more experience in using the system. It may be beneficial to direct group discussions into the problem areas in an attempt to clear up the misunderstandings.

The subordinates who can't manage will soon become aware of this. It would be well to have some training discussions prepared to highlight the management problems. Further use of the PERT COST approach will show them the variables and how to

handle them.

There will be a conflict of projects within the organization. This cannot be helped. The projects must be given priorities and handled accordingly. The time delay, when another project has priority, should be added on to the project completion time and the dates changed accordingly. The work time should not change even though the calendar dates may change.

Special assistance to subordinates.--The results of the project status analysis will identify special problems that can best be handled on a personal basis. The fact that the problem has been identified, and obviously needs a solution, gives the manager the right and duty to inquire personally as to its causes. This inquiry may bring out problems that the subordinate didn't want to bring out in the group meetings. It may be a situation the subordinate has been living with, not realizing that there is a better solution.

The manager should try to coach the subordinates on a personal basis between the periodic review periods. He should not shove PERT COST down their throats; however, the model is handy to explain other problems and to clarify many of the daily problems. As subordinates see its use in solving everyday problems, they will come to accept it and to apply its ideas themselves.

One form of special assistance that is particularly important is for the manager to help the subordinates set up the organizational goals, objectives, and performance measures. This

could be the first project. These measures give the subordinates tangible measures of their actions. They will desire to show the greatest improvement possible for promotion purposes. This sets the stage for the use of a system like PERT COST. It also gives them a means for self-measurement and self-corrective action.

Summary

The control cycle consists of the approval of the project plan, collection of actual data, evaluation of the project status, reports, and follow-up management action.

Summary

The manager, subordinates, and organization all bring constraints to bear upon the effectiveness of the control procedures. The manager must take a soft approach with an immediate goal of improvement, not revolutionary change. He should accomplish this through group participation, minimization of clerical work and details, and maximization of co-operation and co-ordination based on the project totals.

The control procedures are cyclical and consist of approval of the project plan, collection of actual data, evaluation of the project status, reports, and follow-up management action.

Approval of the plan starts with the selection of an idea for further development into a feasibility study which determines its value and the best method of accomplishing it. Once an idea is approved, the manager will coach his subordinates in planning for its accomplishment, to insure that the critical problem areas

are adequately considered.

The collection of actual data is done by the subordinates on their copy of the approved plan. Completions of activities and changes in the planned data are annotated on the plan.

The project status is periodically evaluated, based on the data collected by the subordinates. All new data is added to the project control network and the network reevaluated for its current completion time and costs. Problems are identified and courses of action determined to keep the project in consonance with the original objectives. The networks are revised and reoptimized to reflect the new plan.

Reports should supplement the work done on the project control network. Figure 5 gives a graphic technique that will simplify reporting procedures while still focusing on the results to be obtained.

Follow-up management action will be based on the problems that are identified in the above procedures. Corrective action can be applied in the group discussions or on a personal basis as required.

SUMMARY

Through PERT COST the individual manager can increase his personal effectiveness, efficiency, and economy and, consequently, that of his organization. This is accomplished by improving the manager's ability to analyze, plan, and control specific operations of the organization giving him greater visibility and perspective of, and for, its problems. In government operations, savings of twenty-four weeks and $250,000 have been recorded. In commercial operations, savings of 25 per cent in time and $1,000,000 in costs have been realized.

Costs are integrated into the PERT COST model as the common denominator for all activities, alternative courses of action, and measures of efficiency and economy. The cost objective is to minimize the total cost for the project. This includes both the costs for the project and the costs caused by the project in other areas of the organization. The total cost is minimized at an arbitrarily directed point between or including the normal time, least cost point, and/or the crash time, greatest cost point.

The individual manager will plan with PERT COST at the project level, using the Work Breakdown Structure, project

summary network, and the project control network. Input data to the manager will come from a comparable development of the major work packages by his immediate subordinates. Emphasis will be placed on general plans and estimates based on experience. Through participation in the planning process, the subordinates will learn to recognize the interrelationship of the variables, to develop methods to further refine their estimates, and to solve their own problems.

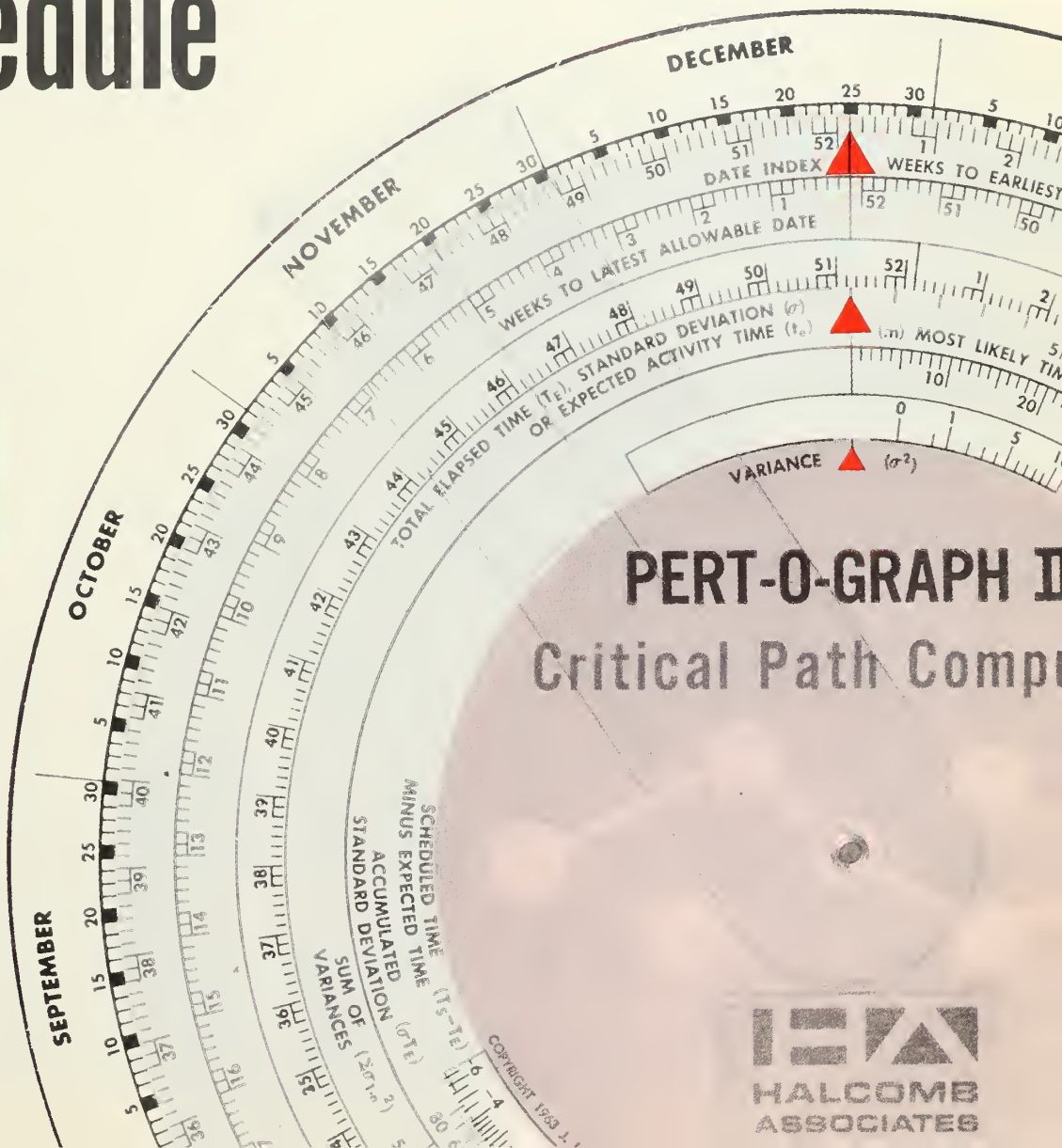
The manager will control the project through the project control network. This is the standard of performance for activities in the project. It must be periodically updated for completions and forecasted changes in data. The network is then revised and reoptimized to reflect the current plan for the operation of the next period. The control cycle consists of approval of the plan, collection of actual data, evaluation of the project status, reports, and follow-up management action.

APPENDIX A

PERT-O-GRAPH KIT

A CONSTRUCTION METHODS
SPECIAL REPORT

ow PERT-O-GRAPH kept fast construction job n schedule



REPRINT FROM...
nstruction ethods AND EQUIPMENT
JUNE 1967

This reprint from **Construction Methods and Eq** tells how James Halcomb, using his remarka **PERT-O-GRAPH** system of Critical Path sch guaranteed a pre-Christmas opening of a C shopping center in spite of six weeks of w rains during foundation construction.

The article explains:

1. How PERT-O-GRAPH network analysis det the best arrangement of work sequences an ments of timing before the project began.
2. How the PERT-O-GRAPH slide rule was u the only computer for solving and updat Critical Path schedule.
3. How the PERT-O-GRAPH Critical Path s was used for effective project management the job on schedule even during conditions could critically delay the project.

You can do this yourself. Learn how to make Cri Path scheduling work for you on your own proj without electronic computers. See special offe the new PERT-O-GRAPH Kit on the back co

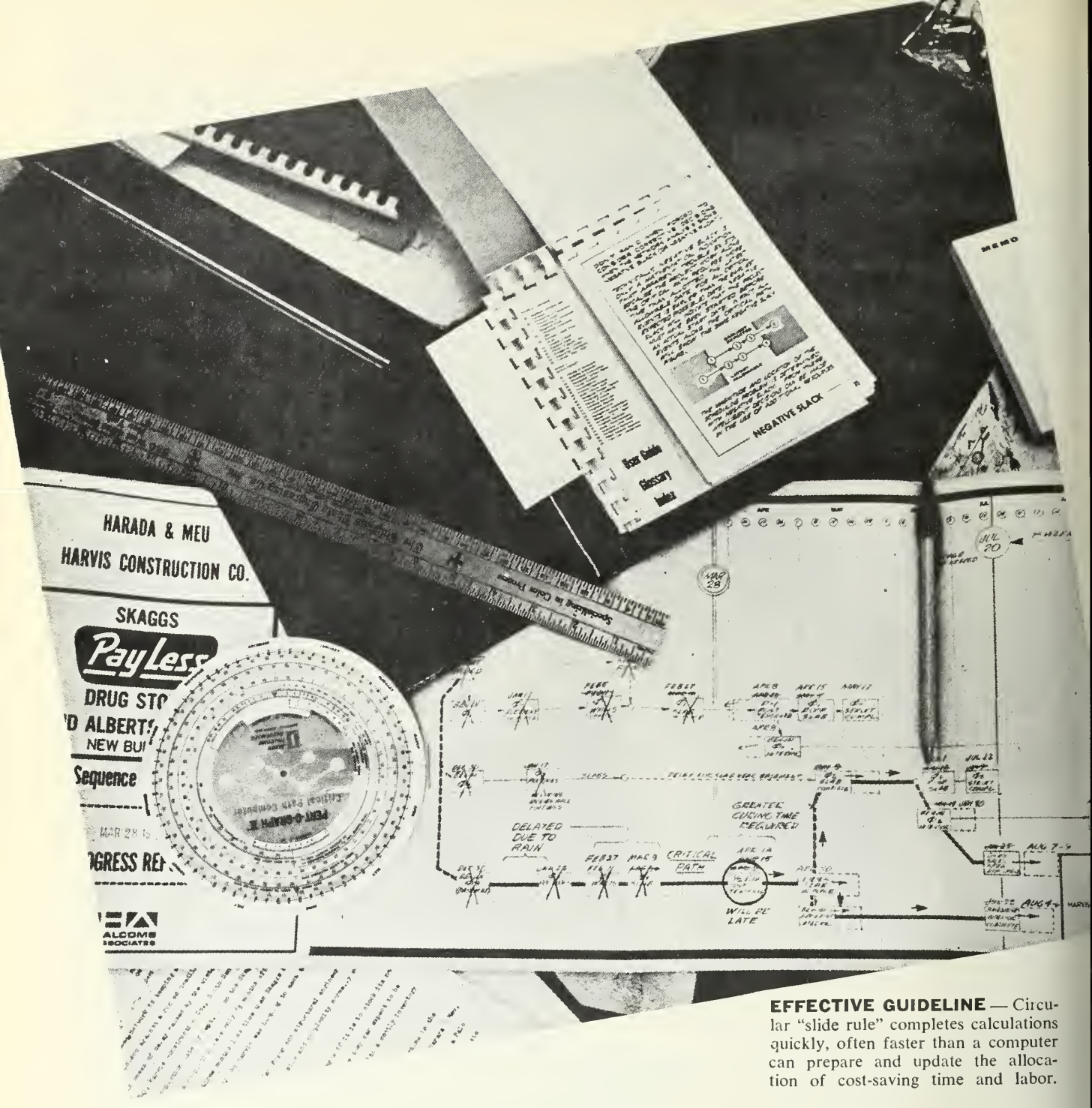
1967

onstruction Methods AND EQUIPMENT

GRAW-HILL PUBLICATION • ONE DOLLAR

RDERS GO TO BED

ld's biggest precast- 25 mi of girders for erial transit — has h to high-produc- ting that sets effi- rds. Story p. 67



EFFECTIVE GUIDELINE — Circular "slide rule" completes calculations quickly, often faster than a computer can prepare and update the allocation of cost-saving time and labor.

A NON-COMPUTER CRITICAL PATH network is keeping a $4 million shopping center, being built in San Francisco against a rugged deadline, "essentially on schedule" in spite of some six weeks of delay caused by the winter's record rains.

As of mid-May, Harvis Construction Co., South San Francisco, expected to meet the contract completion date of Sept. 14 on the Pay Less Drug Stores shopping complex, a completion date only 8½ months after start of construction.

In fact, says Russell H. Fuller, San Francisco structural engineer on the job, the construction of a building of this size and complexity normally would take from a year to 15 months. Mid-September completion is essential for Pay Less if it is to stock its new store for Christmas shopping.

Pay Less has had problems with construction running into overtime in the past, and so this time—on the recommendation of project architect, Harara & Meu, San Francisco—they specified that the contractor retain James Halcomb, a Sunnyvale, Cal., consultant on PERT/CPM, to develop a network schedule and update it every 30 days. Halcomb specializes in the application of non-computerized CPM to relatively small projects.

Harvis job superintendent Eddie Snyder, a newcomer to CPM scheduling, gives the system full credit for the construction miracles he's been working.

"It's been a real education," he said. "A

A computer-eliminating slide rule system produces a "do-it-yourself" critical path method that keeps a complex job on a fast construction schedule despite long spells of bad weather downtime.

Circular Slide Rule Schedules Project With Computer-Like CPM Efficiency

year ago if anyone had said we could build this center in eight months I'd have told him he was crazy."

The 109,000-sq-ft reinforced concrete building—408 x 204 ft, with a 204 x 100-ft basement at the west end—supplements limited parking space on the 8-acre site with roof-top parking. Both the roof and ceiling of the basement are post-tensioned pan joint slabs.

Two moving ramps 86 ft long will connect the shopping floor to the roof parking lot and will move customers and their shopping carts.

The site cuts into a hillside abutting a freeway right-of-way, and the shopping center is backed up against a retaining wall formed of 3-ft-dia caissons on 6-ft centers that were drilled up to 65 ft into the ground at the basement end of the structure.

Harvis is helping the schedule along with a good investment in time saving construction techniques and equipment.

Snyder "gambled" to pick up a good 2½ weeks of time by contracting for a 3-yd rubber-tired loader to do a backfilling and compacting job. He achieved better than the 90% of compaction required in a 500-ft-long stretch of backfill against three basement walls in 2½ days, when the original schedule allowed three weeks for conventional loading and tamping.

Snyder has picked up another couple of weeks by pressing preparations for concrete placements originally scheduled for Mondays so that the pours could be made on Fridays, thus getting two days curing time in over the weekends. He's succeeded in pushing up his schedule in this way in "eight out of ten tries."

Form erection is speeded by use of the Superior single-waler clamp system, and shoring ceiling and roof forms is simplified by the use of Elis clamps for quick adjustment of shore lengths.

Harvis used some 30,000 sq ft of joist pans for maximum efficiency in setting up for concrete placement in the roof and basement ceiling slabs; they placed 500 cu yd of concrete —100 x 140-ft sections—in a pour. Concrete was primarily moved by conveyor for roof placement; by pump for walls and floor slabs.

The job was also speeded by the owner's contracting separately with P&Z Co., Inc., South San Francisco, to place the caisson retaining wall. Harvis had only to gunite between caissons to finish off the wall. No bracing was required except in the basement area, so Harvis crews weren't hampered by having to work around shoring along the wall.

So far, the schedule has been met without overtime, and with no extra costs. Probably, however, two shifts will be put on for finishing work in the basement warehouse,which Pay Less needs by July 20 to start building inventory.

Coordination of and cooperation from the subcontractors—both tied directly to the CPM

schedule—have been the key to keeping on schedule, declared James R. Gummere, Harvis vice president.

"It's a real good lever with subs," says Gummere. "All the major subs were in on the development of the network, and they feel involved in making it work.

"The job's all laid out for the subs to see, and you can tell the sprinkler subcontractor, say: 'Here's where the electricians come in. If you start now you can have a clear shot at it: if you wait a week, you're in trouble.' You can show a man that if he puts more man hours on the job now, he'll save them later on," says Gummere.

For instance, he noted, the electrical subcontractor originally planned on 40 days of work before floor slabs could be placed. With the hard facts of the network schedule before him, he agreed to resequence the work and nearly triple his crew for this preliminary work. With the change, floor slab placement started just 10 days after the electrical subcontractor moved in.

"The subs have been great; every one's been on or ahead of schedule."

Snyder particularly likes CPM's help in allocating the labor on the job. "There's no waste motion," he said. You don't panic and double crew size across the board when you're behind schedule, he explained. You just beef up the crews on the critical path, pulling them off of jobs not in that sequence.

"Why eat up labor on jobs that can wait?" he noted. "When I need to do a job I'll get to it. For instance, work on the ramp wall (the retaining wall supporting the ramp entry to the roof parking lot) can be tacked on anywhere in the schedule."

But the greatest advantage lies in the way the system enforces advanced planning, Snyder stated.

"It helps you hindsight the job before you start," he said. "You can solve a lot of problems before you ever get into them," Snyder declared.

"With CPM you can see what's going to happen and straighten it out in the first place," he said.

The network schedule is flexible, simple to update and simple to revise. An early change in the Harvis network consolidated concrete placement, so that pours of up to 500 yd were made at a time rather than a series of smaller pours. They found that a conveyor system using up to 300 ft of conveyor sections was necessary for the large roof pours; they ran into problems of delay with pumped concrete for the roof.

Halcomb and Harvis project management started development of the CPM network immediately upon the award of the contract, beginning with an orientation meeting with representatives of the owner, the architect, the structural engineer and all major subcontractors—about 20 men in all. The meeting opened with a short course on the application of the PERT/CPM technique.

Both PERT (Program Evaluation and Review Technique), first used on the Navy Polaris missile project in 1958, and the Critical Path Method, first applied to construction by DuPont, were developed for use on the computer to help in scheduling highly complex programs. However, the basic planning concept in each is very simple, and need not depend upon a computer in use on small projects.

In the course of his consulting work, Halcomb has devised a circular "slide rule," a PERT-O-GRAPH, that not only makes quick work of the necessary calculations but also actually can be faster overall than a computer on preparation and updating of complex networks. Use of the PERT-O-GRAPH eliminates the need for preparation of punched cards, and for the re-translation of computer data into network form.

"It's a real good lever with subs. All the major subs were in on the development of the network and they feel involved in making it work."

In his zeal for spreading the benefits of network planning, Halcomb has written a handbook, and sells it along with the PERT-O-GRAPH to contractors for "do it yourself" CPM.

In the preliminary meeting of all principals, contractor and subs also faced up to the tough problems inherent in the short deadline for completion of the project, recognizing that all segments of the job had to be accelerated, and that with conventional practices they'd never make it.

Halcomb and contractor project management—Gummere, Snyder and Estimator Albert F. Richards—then went into three days of planning meetings.

First they decided to break the over-all job into three phases—erection of about half of the main floor structure, excavation and construction of the basement, and construction of the remaining half of the store's main floor structure.

"Milestone" goals for the construction were then established, about 25 of them, for such achievements in the three phases as placement of footings, erection of walls, placement of roof slabs, post-tensioning of roof slabs, interior finishing, etc.

The network team then filled in all the various "activities" necessary for completion of these goals, and worked out the sequence of

"events"—figuring out the various job priorities. "Events" in the PERT/CPM vocabulary are the completed steps in a construction sequence; "activities" are described on the lines connecting the events—as "shore," "set steel pans," etc.

In the third day of the meetings the team filled in the estimates of the time needed for each activity, working from their own job experience and countless phone calls to subcontractors. The two major subs—electrical and plumbing—were brought into the meeting to add their knowledge to the scheduling around their activities.

On many construction sequences, project management and subs together can predict fairly precisely how much time a job will take. When there are uncertainties, however, a weighted formula built into the PERT-O-GRAPH takes three separate estimates—"optimistic," "pessimistic" and "most likely"—and comes up with a statistically tested "expected" time.

Halcomb then took the network roughed out in these sessions and prepared four strip charts

"It helps you hindsight the job before you start. You can solve a lot of problems before you ever get into them."

and an "overall construction sequence" that showed just the "milestone events" and the critical path, to give a quick overview of job progress, and three detailed networks for the three phases of the job.

The critical path goes through the sequence of job operations expected to take the longest time.

Finding this path can often be a tedious manual task, or be expensive if the electronic computer is used. Here is where the Pert-O-Graph makes its greatest contribution. By using a special calendar scale, the duration times for the project were converted directly into earliest dates, late dates, and slack (float) from which the critical path was "computed" in less than an hour. This is about one-fourth the time it would have taken to fill out the forms from which electronic computer cards are punched. And it eliminated computer rental charges.

On this shopping center, the critical path ran through the basement construction, and so problems mounted on problems as rains first delayed the excavation of the basement and placement of footings and then—when the excavation turned into "Lake Snyder"—prevented not only construction of the basement and the floor above but also of the adjacent first floor slab and the erection of the building segment over it.

Once the heavy rains stopped it took ten days to pump and dry the basement and clean sediment off the footings.

Thus success in Snyder's "gamble" to speed the backfill around basement walls with the 3-yd loader and pick up the 2½-week chunk of lost time was a major coup. One gamble lay in whether or not the weight of the rubber-tired loader rolling over the fill as it placed it would achieve the necessary 90% compaction. Soils testing engineers checking out the fill as it was placed found it worked to perfection, actually achieving 95%.

Another lesser gamble was on whether stretches of the wall not braced by the section of the post-tensioned ceiling in place would be adequately supported against the backfill pressure by the 10 x 10 kickers. Again, the gamble won.

Once the basement walls were backfilled, columns could be erected on the walls (the 10-in. basement walls were thickened to 22 in. at the 48-in. beams to carry the anchor-bolted steel columns), and work could proceed on placement of the adjacent ground floor slab and on shoring for and placement of the remainder of the ceiling and roof slabs.

The architect and engineer settled on the post-tensioned pan joist roof to get the 50-ft spans required by the owner with minimum slab weight. The 10 x 10-in. columns of 1¼-in. steel are set in 50-ft centers the length of the building, 36-ft centers on its depth. The columns are designed to carry a second story on the building for possible expansion of shopping area.

Beams and joists in the parking roof are 24½-in. deep including the 4½-in. slab. Beams are 48 in. wide and joists are from 8 to 16 in. wide; 40-in. pans were used. An expansion additive, ChemComp, in the rock concrete in the parking deck roof together with the two-way post-tensioning is expected to keep shrinkage cracking at a minimum so that waterproofing will be required only at the joints between the pours.

Pans in the basement roof are 30 in., and while beams in this roof are also 48 x 24½ in., depth of the joists is just 14 in. below the 4½-in. slab. Joists are from 5½ to 13 in. wide.

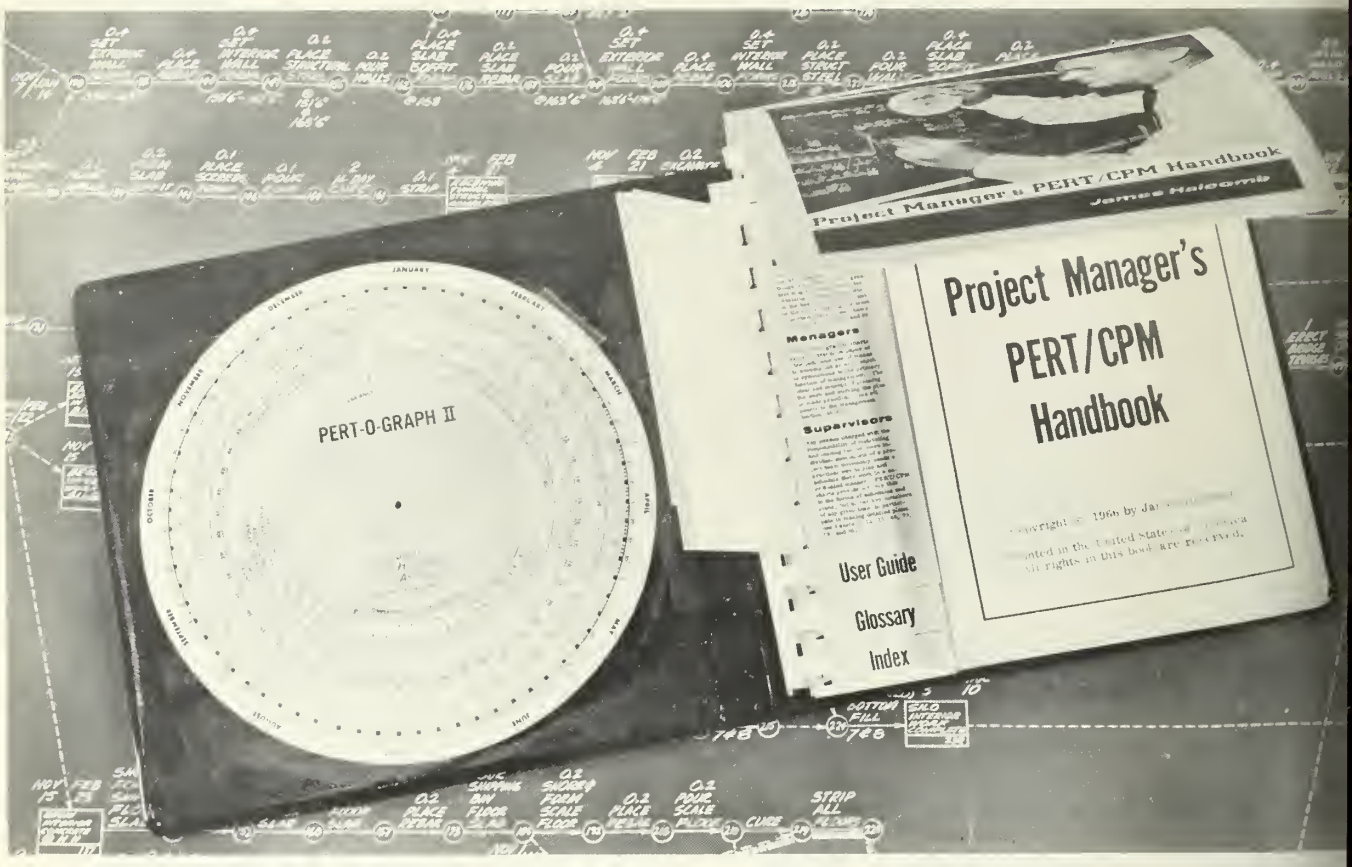
Sono-tube reinforced concrete columns 10 in. in dia are set on 25-ft centers between the steel beams in the basement to give added support to the lighter weight basement ceiling structure.

The moving ramp, a Sandvik Steel Inc., "Movator," will be the first installation of its type in a shopping center in the U.S., and offers a nice solution to the problem of moving purchases from the store level to roof-top parking spaces.

The endless belts in the moving ramps are made of heavy-gauge spring steel in one piece, permanently bonded with a wide-rib, narrow groove rubber tread.

A SPECIAL OFF

How you can become a scheduling expert



Order your own PERT-O-GRAPH Kit. Complete in one package . . . the know-how of Critical Path sched and the computing instrument . . . all you need to make PERT/CPM work for you. Kit contains PERT-O-GR Computer, "Project Manager's PERT/CPM Handbook," and quick reference guide . . . bound in prote vinyl binder.

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Slide Rule Maps Critical Paths

Developing a new product can e easier if you plot the key sks in a logical sequence.

The PERT technique can help. nd the only tool you need is a nall, circular slide rule.

A pocket-sized calculator is ex-nding the usefulness of the man-ement technique known as PERT rogram evaluation and review chnique). The calculator, a plastic rcular slide rule, is designed to ndle all necessary computations r a PERT project.

The whole idea of the device is bring PERT's efficiency to com-nies other than those engaged in developing huge systems where computers are essential. It should, for instance, be a useful tool in the design and development of new products.

Product Design—J. L. Halcomb, of James Halcomb Associates, Palo Alto, Calif., developed the new planning tool. At this year's Design Show in New York, he also presented a detailed discussion of how the PERT technique can be used in product design.

He noted that the nature of product development suggests it be programmed over a period of time according to a logical sequence of events. And here's where PERT excels as a management aid.

D IT YOURSELF: This simple slide rule can be used to "pert" the de-lopment of new products. It permits more realistic time estimates.

First, a product development program is described as a network of sequential major phases. Each of the major phases can then be further detailed.

Flow of Events — Basically, a PERT network is a graph constructed of circles and interconnecting lines. The circles represent events, or points in time. They may, for example, be key decisions, preliminary designs, or acquisition of important equipment.

Each event is connected with an arrow representing activity. Thus, interconnected by activity lines, events would spread across a piece of paper from left to right.

Later, each activity arrow is defined in terms of elapsed time. Some events are connected with dotted lines to show they are purely logical relationships and will require no time.

When the planner's rough "map" has taken shape, estimates are made of the time it will take to get from the first event to the second, and so on to the end of the activity network. Estimates can be made using the slide rule.

There are three preliminary estimates: Most likely, optimistic and pessimistic. These are averaged to arrive at a single expected time for the event.

Add the Times—Starting from the first event, the expected times are added sequentially to find the accumulated elapsed time for each event. The sum of all individual events becomes the earliest expected date for final project completion.

Next, the latest allowable date is calculated for each event. In other words, how much time can be spared?

Those events with the least slack —where the latest and earliest dates are almost equal—are critical. And the critical path from beginning to end of the project will be where these events interconnect.

12 NEW MANAGEMENT PLANNING PERT/CPM AIDS

PRODUCT INFORMATION
PRICING INDEX
ORDER FORM

HALCOMB ASSOCIATES

1

PERT-O-GRAPH KIT

Basic package of the PERT-O-GRAPH System. Shows how to provide management with visual time and event control of any project, plan forecast, or commercial activity. Comprehensive Handbook is printed in unique cartoon style of 92 illustrated panels to show how to ma CPM networks and how to figure schedule dates using the PERT-O-GRAPH Critical Path Computer. Consists of complete instructions, chart and the computing instrument itself. Includes "Project Manager's PERT/CPM Handbook," PERT-O-GRAPH Computer, User Reference Guide, and is bound in a protective vinyl jacket.

$24.5

2

CRITICAL PATH COMPUTER

The pocket sized calculator for extending the usefulness of the PERT/CPM management technique. Circular slide rule shape has scales calibrated for figuring all PERT/CPM times, dates, and other data from network time duration estimates. Key answers are read direct continuous calendar scale. Entire calculation procedure requires less time than the electronic computer because of no forms to fill out punch, or complicated printouts to interpret. Scales are easy to read and are so accurately calibrated that its user is characteristically of making mistakes. The unit is manufactured with durable materials and engraving process to assure high quality and long life.

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3

EXECUTIVE CREATIVITY BOARD

A revolutionary new concept in extending a manager's personal ability to get things done with PERT/CPM. Here is a magnetic wall bo makes it easier for the executive and his decision-making team to get involved in the goal-setting and strategic planning procedure. visual display allows them, as a team, to set overall objectives, spell out important milestones, eliminate irrelavent details, and finally each into a logically interelated visual pattern. The 2 x 3 inch magnets allow enough information to be displayed quickly in bold black le to be comfortably viewed by all members of a group within a large room. The wall board is manufactured with a walnut frame, a ferrous surface to attract the magnets, and covered with protective Mylar for easy marking and cleaning.

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4

LEADER'S TELESCOPIC PRESENTATION POINTE

A presentation aid for any speaker using PERT/CPM charts in management briefing sessions. Because the chart becomes an excellent for making proposals or for reviewing past work, the leader can make a more convincing presentation especially if he applies the p approach. The pointer makes it easier to follow network logic or to trace the critical path. Making speeches along with the PERT/CPM actually be interesting and easy for the speaker and the audience. Merely point to a particular item, discuss it, then move on to the It's like following a set of notes. Be prepared for your next presentation. Use our handy chrome finished pointer which telescopes to a handy pen size and has a pocket clip for ready use.

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5

MANAGEMENT PLANNING PROCEDURE FORMS

For the first time the basic planning process itself is simplified by organizing and procedurizing this difficult process. These forms we to ensure adequate "homework" before PERT/CPM network development. Most failures or disappointments in network applications can traced to inadequate preparation before actual network graphics generation. These forms enable their user to get started even in the mo project planning areas, by actually compensating for lack of experience in management planning. Procedural requirement for using guarantees that key individuals prepare themselves before group planning sessions where the PERT/CPM chart integrates the total tea set consists of five pads with 100 forms in each pad.

$14.50 per

6

EARLIEST/LATEST TIME PEN

Dramatically shows the most vital difference between PERT/CPM and all other scheduling systems, i.e., that every event has two da given project, the earliest date when calculated from start, and the latest date when calculated from project completion. Patented "tw ball pen writes in two colors, automatically, indicating 'Earliest' dates in blue, 'Latest' dates in red. Excellent for first visualizing the scheduling problem, even in early network sketches. Not only shows the critical path (where the earliest and latest dates are closes but precisely how non-critical the slack paths are. A precision instrument fashioned in gold — useful in many PERT and non-PERT applications.

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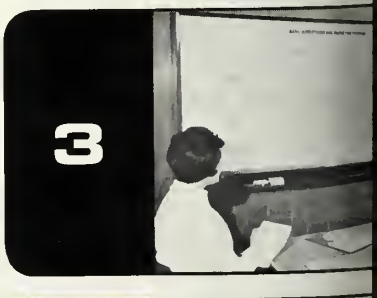

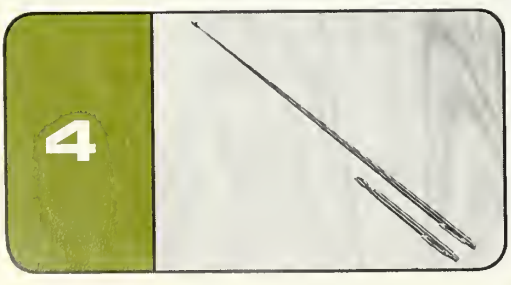

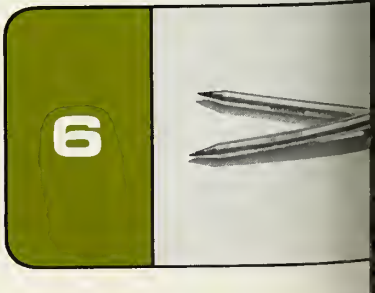

MANAGEMENT MILESTONE EVENT LABELS

7

es the PERT/CPM procedure for initial management planning. Useful either for direct "authoring-as-you-go" network preparation or for yout by graphics specialists after the original network has been roughed out by management planners. Labels can be hand-lettered or pencil or with a standard typewriter from the continuous roll. Labels are made from tough transparent material for use in any kind ion process including ozalid prints from a tracing vellum base. Paper roll backing is etween each label for separating and organizing event sequences prior to adhering chart surface.

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PERT/CPM NETWORK LAYOUT TEMPLATE

8

and speeds up network preparation during the several phases of sketching and finalizing the graphics process. Minimizes drafting llowing the use of new inking processes, where network drafting normally requires the use of a pencil. Template is individually ma- ecision tolerances from a 4X master tooling die. All standard PERT/CPM events, arrows, nodes, and other useful network symbols ue template. CPM type activity sequences can be developed quickly by allowing three symbols at a time to be drawn with only one f the template. Unit is machined from bright orange fluorescent material preferred for template use. d edge is compatible both with ink pens and drafting pencils.

$9.50 ea.

NETWORK DRAFTING PEN

9

ard of excellence in appearance and readability of PERT/CPM networks is now possible with this new fibre-tipped drafting pen. Effec- es the pencil and can be used with any tracing vellum. Erases without smudging or ghosting faster than pencil, using a standard motor- r. Compatible with drafting templates and ideal for free hand lettering used in most PERT/CPM networks. Eliminates most of the hon with pencil drafting because of no need to apply pressure to get a dense image. Improved pen design has longer lasting point he ink reservoir. Dense black ink makes excellent ozalid images or photo reductions never ble with the pencil.

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INDUSTRIAL PERT/CPM APPLICATION KIT

10

ealth of practical ideas, sample networks, materials, tools, and aids for using PERT/CPM in the development of the five major se- ses of the life cycle of a typical new product. Kit includes a special set of PERT/CPM seminar instructions featuring sample networks pared for industry application. Excellent for most key people in industry including R & D managers, engineering managers, production ustrial engineers, marketing executives, general managers, and purchasing agents. Useful to d experienced PERT planners in discovering broad new applications of PERT / CPM in industry.

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MARKETING PERT/CPM APPLICATION KIT

11

nyone charged with the responsibility of developing or monitoring marketing plans. Shows how to use PERT/CPM to derive and set and develop all the logical steps of properly introducing a new product on to the market place. Kit includes seminar instructions mple PERT/CPM network examples showing every important milestone and interconnecting activity from early market research to the ty of a commercially successful new product. For example, conducting the test market, conceiving and following through with a win- ing campaign, getting the best possible publicity from a public relations program, selection and the development of the proper dis- nnels, and much more. Excellent for use by key people in advertising agencies, marketing, sales, ns, and general management.

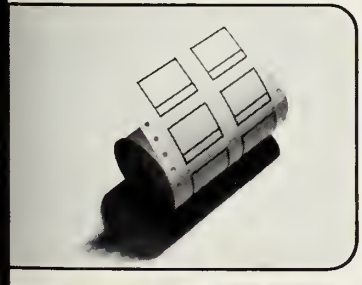
$49.50 ea.

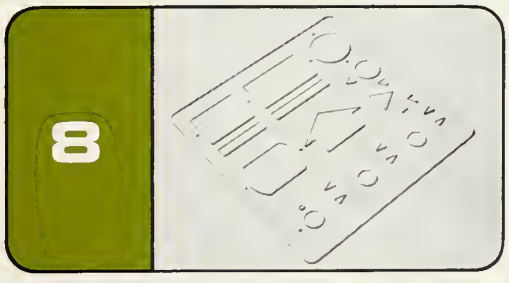
CONSTRUCTION PERT/CPM APPLICATION KIT

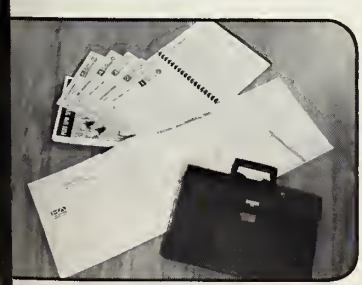
12

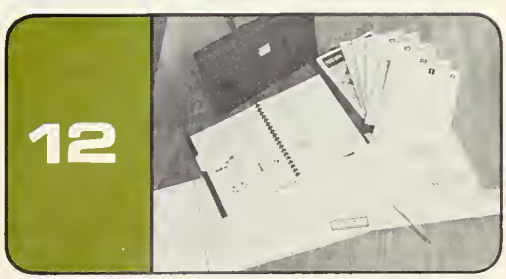
ecially for the construction industry, this kit shows how the key man in construction can effectively use PERT/CPM for planning and project well within the time allowed, yet not exceeding budget commitments. Shows how to keep eleventh hour overtime expenses hift operations to an absolute minimum even when things go wrong due to rain, strikes, or equipment breakage. Kit shows how to tical Path schedule without expensive electronic computers. It also explains how to make a PERT summary of management milestones an effectively replace the bar chart. Kit includes sample networks of several types of structures to work out a detailed construction sequence and how to figure correct duration times and optimum signed to each activity.

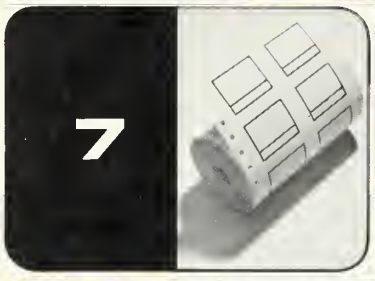
$49.50 ea.

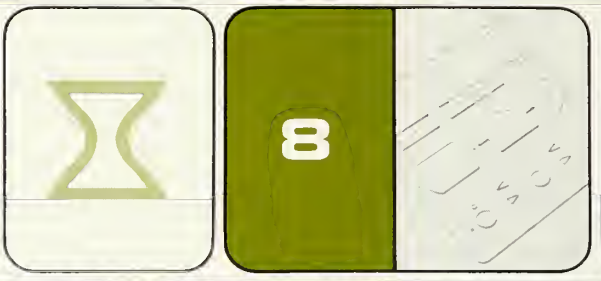


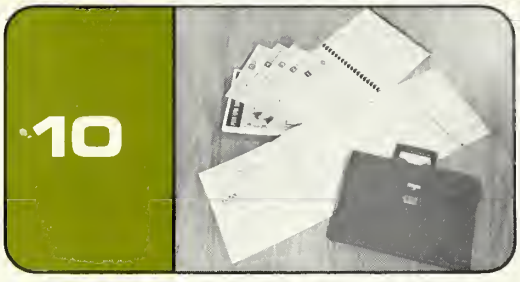


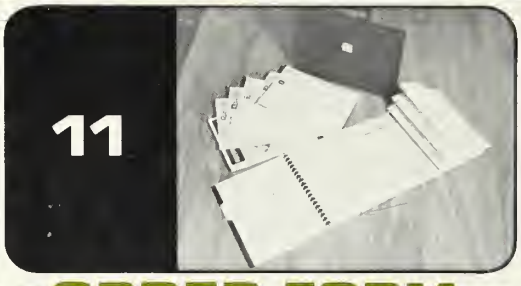












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HALCOMB ASSOCIATES
149 San Lazaro Avenue
Sunnyvale, Calif. 94086
Telephone (408) 245-3131

HALCOMB ASSOCIATES

	Item Descriptions	QTY.	Price
1	PERT-O-GRAPH Kit		$ 24.50 ea.
2	Critical Path Computer		$ 9.50 ea.
3	Executive Creativity Board		$295.00 ea.
4	Leaders Telescopic Presentation Pointer		$ 2.98 ea.
5	Management Planning Procedure Forms		$ 14.50 per set
6	Earliest/Latest Time Pen		$ 2.95 ea.
7	Management Milestone Event Labels		$ 24.50 per 1000
8	PERT/CPM Network Layout Template		$ 9.50 ea.
9	Network Drafting Pen		$ 5.95 per dz.
10	Industrial Manager's PERT/CPM Application Kit		$ 49.50 ea.
11	Marketing Manager's PERT/CPM Application Kit		$ 49.50 ea.
12	Construction Manager's PERT/CPM Application Kit		$ 49.50 ea.

Please send descriptive literature for the following items:

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
7 ☐	8 ☐	9 ☐	10 ☐	11 ☐	12 ☐

PLEASE SEND TO

NAME _____
TITLE _____
FIRM _____
ADDRESS _____
CITY _____ STATE _____ ZIP _____

PLEASE INVOICE TO (IF OTHER THAN AB

NAME _____
TITLE _____
FIRM _____
ADDRESS _____
CITY _____ STATE _____ ZIP _____

SAVE SHIPPING CHARGES...

We will be pleased to invoice rated firms, but to save the expense of and extra bookkeeping, you can send your check with your order shipping costs.*

☐ Enclosed is $_____ Ship postage paid
(California residents add 5% sales tax)
☐ Invoice, plus shipping charges
*(Item 3, Executive Creative Board, FOB our plant in either case)

SIGNATURE _____

his PERT-O-GRAPH KIT
ill make you a scheduling expert!

SHOWS YOU HOW TO:

- Make PERT/CPM calculations without electronic computers
- Read, interpret PERT/CPM charts
- Maintain a PERT/CPM system within your budget
- Sharpen and define overall goals and objectives
- Map out a winning strategy
- Find the Critical Path (Total Project Time)
- Make accurate judgments in timing
- Motivate creative activity
- Keep tabs on job progress
- Make the laws of chance work for you
- Conduct management briefings
- Avoid costly effects of delays
- Design and operate a "Decision Center"
- Communicate the right decisions

SHOWN ACTUAL SIZE

The PERT-O-GRAPH KIT

Enables you to quickly learn PERT/CPM skills, set up planning networks, and save time and effort when working out the Critical Path schedule for any project.

Takes the mystery out of twentieth-century planning techniques.

COMPLETE IN ONE PACKAGE

1. PERT-O-GRAPH SLIDE R

Heart of the Kit is this precision ment, accurately calibrated in e time units. Time scaled for imm readout based on a continuo month calendar cycle. Quickly lates earliest dates, latest date (float) time, total project time (c path), and other needed data A all calculations to be easily m rectly on the network without l cards or tabular printouts

Contents

Panels

User Guide

Glossary

Index

THE PERT-O-GRAPH SYSTEM

Project Manager's PERT/CPM Handbook

FERENCE SECTION

you a clear, overall in-
tion to the Kit and its
keyed five ways: (1)
nts arranged by section
nce, (2) Identification of
ndbook's 92 illustrated
(3) User Guide keyed
ur job function; (4) A
y of terms peculiar to
CPM, and (5) An alpha-
subject index.

3. PROJECT MANAGER'S PERT/CPM HANDBOOK

Comprehensive volume loaded with tips on PERT/CPM gained from years of practical experience — displayed in unique illustrated style. Explains, step-by-step, ideas of interest to the beginner or expert. A teaching text, a master reference guide. **Introduction** section leads reader into the subject. **Analysis** of problems made clear, using network approach. **Computation** shows, with actual examples, how to use the PERT-O-GRAPH. The **Management** section gives you the key to successful, effective management. The final section, **Implementation**, shows how to start using PERT/CPM and how to keep these techniques working for you.

THE NEWEST PERT/CPM TOOL FOR:

- Engineering project management
- Planning construction projects
- Medical research programs
- Launching new businesses
- Organizing advertising campaigns
- New product introduction
- Planning military strategy
- Production scheduling and control
- Planning company mergers
- Coordinating disaster recovery
- Making displays for management
- Monitoring procurement cycles
- Activating manufacturing facilities
- Fund raising programs
- Cash flow and cost accounting
- Government project administration
- Managing architectural design
- Business expansion planning
- Obtaining bank loans
- Subcontract project management
- Marketing programs
- Charting R&D breakthroughs
- Highway construction projects

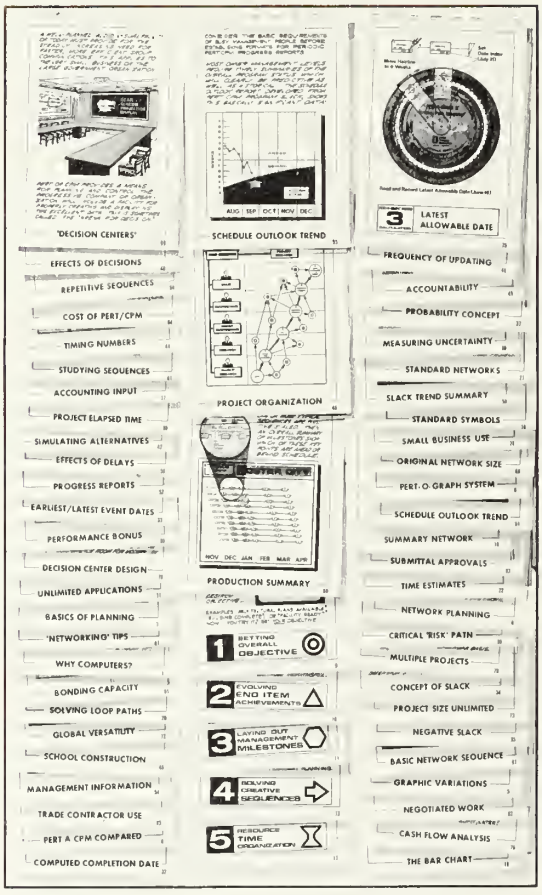
WHO USES PERT-O-GRAPH?

Xerox
Lockheed Electronics Co.
Sears, Roebuck & Co.
NASA
Stewart-Warner
3-M Co.
Stanley Tools, Inc.
Air Canada
North American Aviation
RCA
Central Intelligence Agency
Otis/Reflectone
IBM
Kaiser Engineers
Ohio State University
Dow Chemical Company
U.S. Naval Postgraduate School
Polaroid Corporation
Bechtel
General Electric
Kimberly-Clark Corporation
Fiat (Motors)
General Foods
Federal Aviation Agency
Stanford Medical Research Center
Mobil Oil Company
Israel Defense Ministry
United States Rubber
Motorola, Inc.
Texas Instruments
United Air Lines

The PERT-O-GRAPH KIT

"All you need to make PERT/CPM work for you," never before available in any as a complete package! Basic knowledge — Skills training — practical "how to proaches — and the computing instrument. Kit contains the PERT-O-GRAPH puter, illustrated handbook and quick reference guide to the kit.

92 ILLUSTRATED PANELS



PERT-O-GRAPH SLIDE RU

The slide rule approach to PERT calculat the biggest breakthrough in making PER popular since the original development of under the direction of Admiral Raborn Polaris Program in 1958. More than 25,000 O-GRAPH Computers are now in use — the U.S.A. and in every major nation in t world — used by engineers, scientists, ma contractors, builders, key men in governme many others. The PERT-O-GRAPH Syste made it possible for thousands of busine and professionals to benefit from PERT an — where use of the electronic computer is venient or financially impossible.

PRACTICAL: With the PERT-O-GRAPH, it sense for the first time to apply PERT project, large or small.

ACCURATE: The PERT-O-GRAPH is a pr instrument with direct readout so accurate brated that it is characteristically incapa error. No key punch or programmer errors

VERSATILE: The PERT-O-GRAPH has capacity for use on small or large PER programs — no core memory limitations.

PORTABLE: The PERT-O-GRAPH is small to carry anywhere — in a coat pocket or bri

QUICK: The PERT-O-GRAPH provides fast a A typical critical path can be "computed" than half the time it takes to manually fill forms from which the electronic computer are punched!

COMPLETE IN HANDSOME VINYL BINDER

Carry your PERT/CPM capability with you to the conference room, the laborato the field construction site. Binder holds and protects your PERT-O-GRAPH Com Project Manager's PERT/CPM Handbook, and Quick Reference Section in one package. Gold embossed on black vinyl.

HALCOMB ASSOCIATES

The PERT-O-GRAPH KIT

$24.50 *Postpaid*

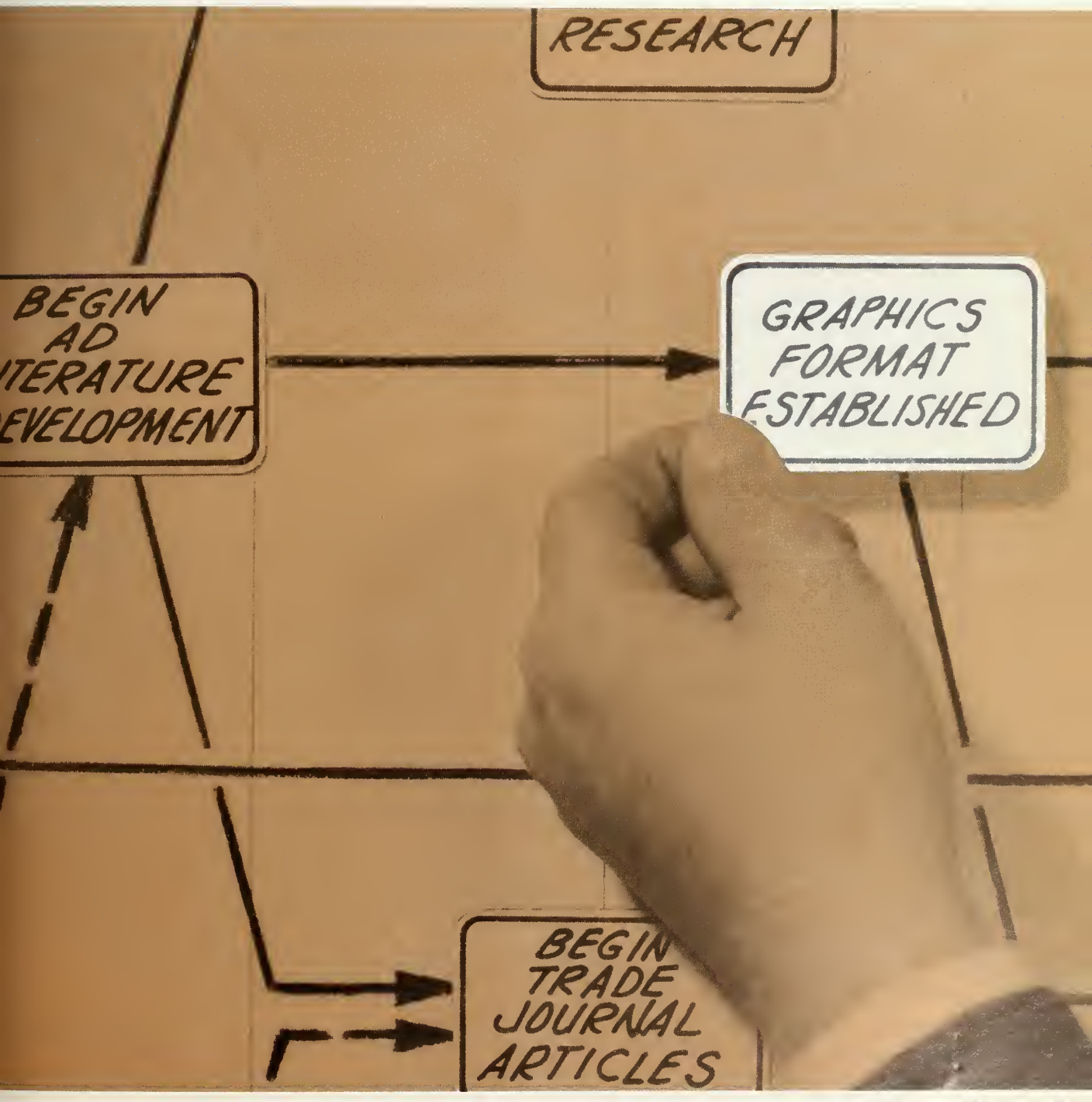
ORDER YOURS TODA

Use handy enclosed return card or send your purchase order to

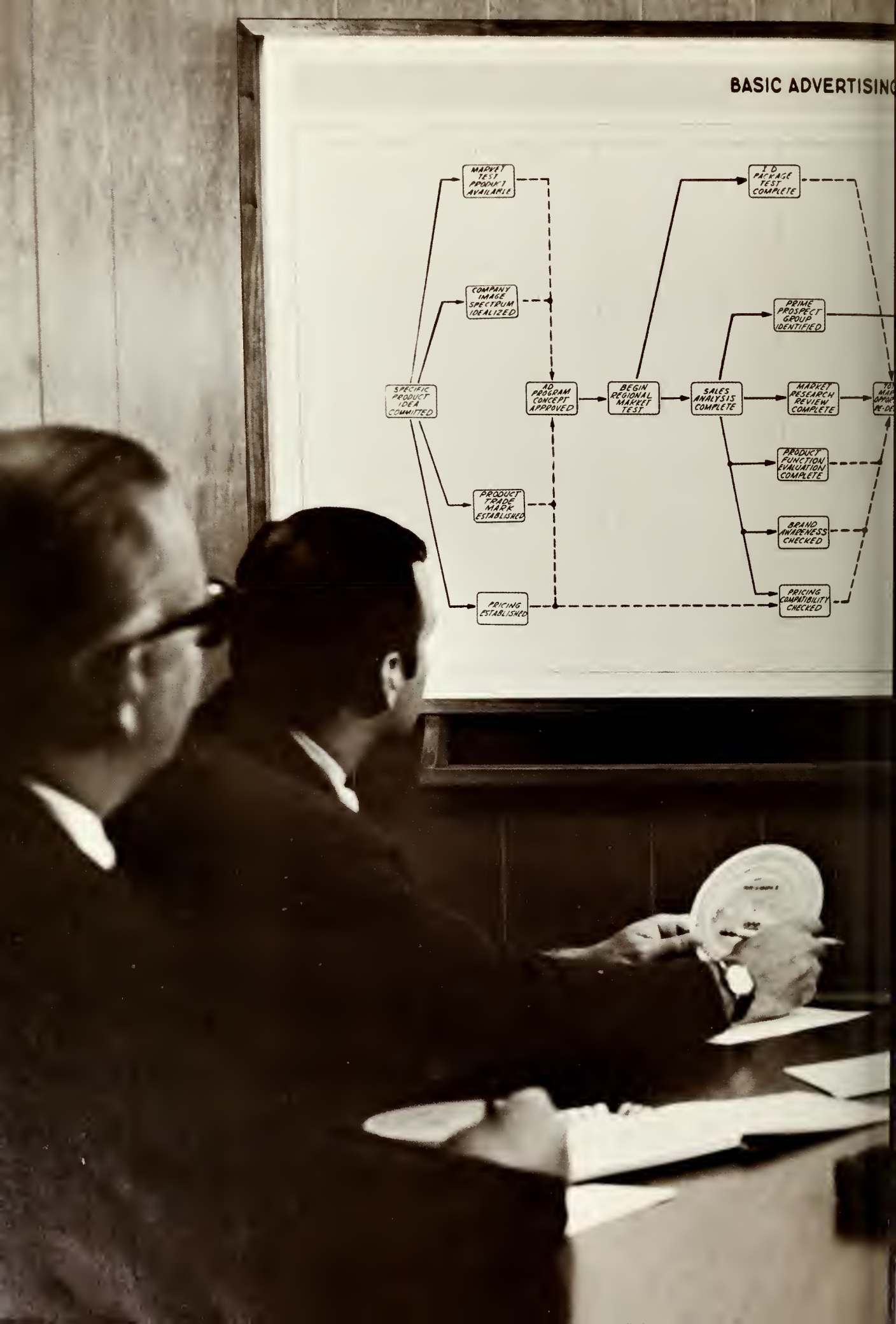
HALCOMB ASSOCIATES
149 SAN LAZARO AVENUE
SUNNYVALE, CALIFORNIA 94086
Area Code 408 245-3131

LITHO

NEW Flexible Tool for Creative Planning



HALCOMB ASSOCIATES


BASIC ADVERTISING
MARKET TEST PRODUCT AVAILABLE
I D PACKAGE TEST COMPLETE
COMPANY IMAGE SPECTRUM IDEALIZED
PRIME PROSPECT GROUP IDENTIFIED
SPECIFIC PRODUCT IDEA COMMITTED
AD PROGRAM CONCEPT APPROVED
BEGIN REGIONAL MARKET TEST
SALES ANALYSIS COMPLETE
MARKET RESEARCH REVIEW COMPLETE
PRODUCT FUNCTION EVALUATION COMPLETE
PRODUCT TRADE MARK ESTABLISHED
BRAND AWARENESS CHECKED
PRICING ESTABLISHED
PRICING COMPATIBILITY CHECKED

he answer to problems
f visual presentation
f strategic
anagerial functions

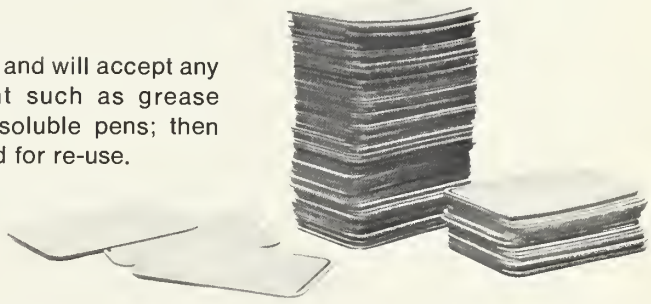
combination of a white-surfaced graphic display unit and milestone organizer
agnets revolutionizes the old blackboard idea into a much
proved, flexible tool for aiding the creative thought process based on the
markable PERT system.

deliberate choice
f effective approaches
an interactive
anager/display system

e walnut edged 3′ x 6′ white surface of the PERT-O-GRAPH Board is attracted by
agnetized milestone event symbols which make up the network-
sed management plan.

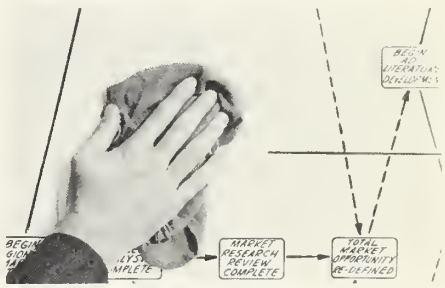
lestone organizer magnets

ade from a flexible material impreg-
ted with magnetized ferric oxide mol-
ules, the 2″ x 3″ magnets are large
ough to display milestone events
ich will be visible even when viewed
typically larger group briefing ses-
ns. The white epoxy surface, silk
reened with a black border, is vir-
tually indestructible and will accept any marking instrument such as grease pencils and water soluble pens; then later can be cleaned for re-use.



aphic writing surface

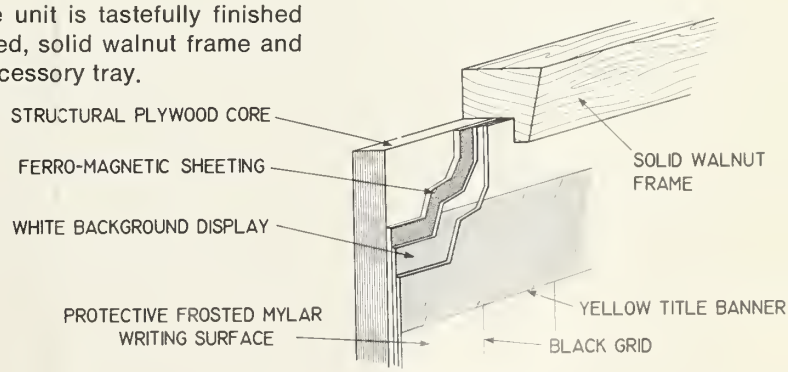
er discarding dark magnetic black-
ards, white chalk boards, or expend-
e paste-up chart surfaces over mag-
ic surfaces, the problem of an ideal
ite "writing" surface was solved by
ng a non-glare frosted Mylar surface
er a universal time grid. The ad-
ntages offered, in addition to the psychologically desirable white surface for display purposes, is that the surface can be cleaned easily and re-used instantly.



refully selected
nstruction design

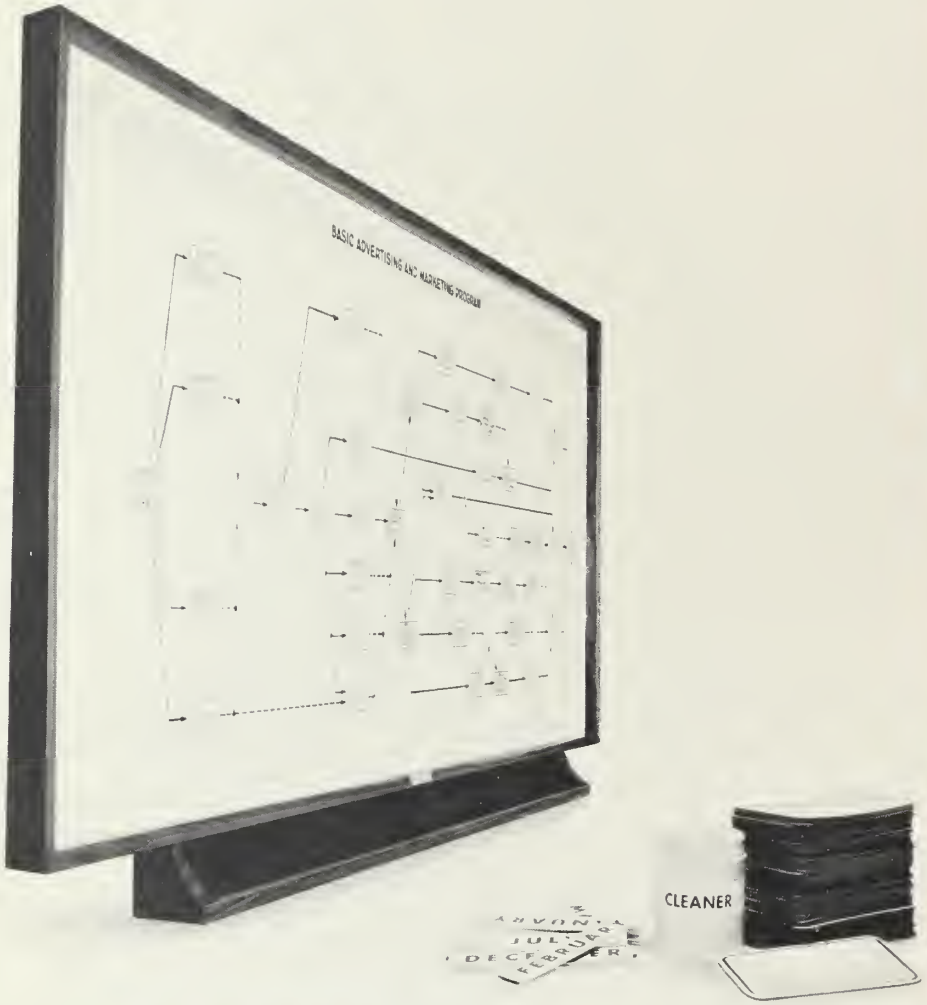
s unit is manufactured of durable,
quality materials, designed for func-
nal utility and long life. The system of
gnetic and written network symbols
a white background display is
hieved through an original design
ncept consisting of a layer-by-layer
sembly of materials chosen to fulfill
optimum function of structure, mag-
ic characteristics, white background
play, and non-glare durable writing
face.

The entire unit is tastefully finished with a stylized, solid walnut frame and matching accessory tray.



Here's what you get

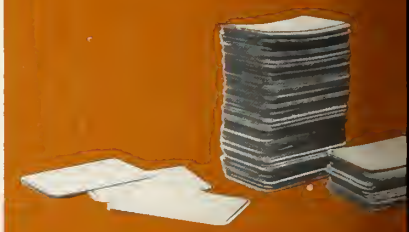
The PERT-O-GRAPH Magnetic Board becomes a complete system with a kit of standard accessories consisting of the main display unit, an accessory tray which attaches to the bottom of the unit, a flush wall-mounting bracket, 50 milestone organizer magnets, 24 monthly calendar magnets, and a jar of instant surface cleaner.



Additional accessorie

Special purpose magnets

The PERT-O-GRAPH Magnet becomes a more versatile too wide variety of magnets alrea ventory or made to your ord know the size, color, shape, o imprinting to suit your particul For example, visual control c production control, inventory p computer use scheduling, jo scheduling, or hundreds of oth cations for planning and sc can be effectively developed application which could ben better use of available time.



12 new aids to PERT/CPM management planning

A complete new line of spec ucts has been developed by H Associates to aid any manag plementing the PERT/CPM sy a more professional approach agement planning and control below and return to us for addit formation.

ORDER FORM

PERT-O-GRAPH Division
HALCOMB ASSOCIATES
149 San Lazaro Ave., Sunnyvale, Calif. 94086
Telephone (408) 245-3131

HALCOMB ASSOCIATES

Please send to

Name_____

Title_____ Firm_____

Address_____ City_____

State_____ Zip_____

Please invoice to (if other than above)

Name_____

Title_____ Firm_____

Address_____ City_____

State_____ Zip_____

Please send

☐ **PERT-O-GRAPH Magnetic Board with standard accessories $295.00**

☐ **Additional 2"x3" Milestone magnets available at $1.00 each. Quantity** ____

Please send descriptive literature for t following:

☐ Special Purpose Magnets

☐ 12 New PERT/CPM Aids to Manageme Planning

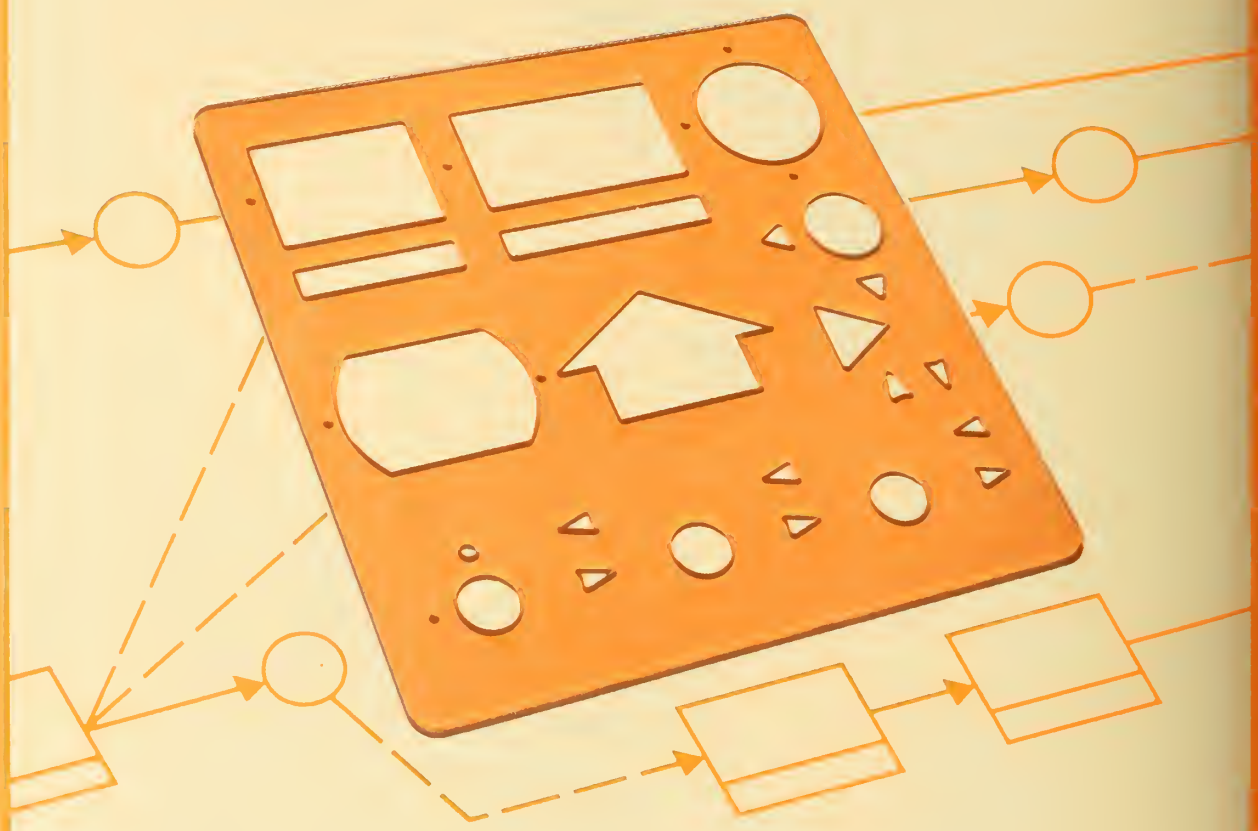
☐ Enclosed is $_____
(California residents add 5% sales tax)

☐ Invoice rated firm
(Freight collect F.O.B. Sunnyvale in either case)

Signature_____

HERE'S HOW...

Professionals are using the precision PERT-O-GRAPH PERT/CPM Layout Template in network preparation.



Heavy weight fluorescent plastic with beveled edge allows use of inking instruments as well as pencils

PERT/CPM LAYOUT TEMPLATE

FOR CPM

Align CPM nodes along guide line, then draw up to three nodes at a time.

Draw arrow points adjacent to nodes, then interconnect to complete arrow.

VARIATIONS

- Time Scaled Networks
- PERT/CPM Combinations
- Activity-on-Node Systems
- Precedence Diagrams
- Updating Actuals

FOR PERT

Align PERT event symbol along guide line on paper

Complete PERT event by moving template up to align drawn event with bottom edge of smaller rectangle.

ORDER YOURS TODAY!

PERT-O-GRAPH
PERT/CPM
Layout Template
$9.50 *Postpaid*

PERT-O-GRAPH Division
HALCOMB ASSOCIATES
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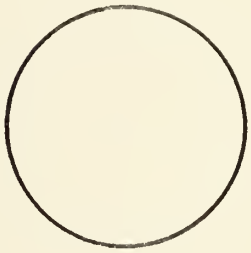
Sunnyvale, Calif. 94086
Telephone (408) 245-3131

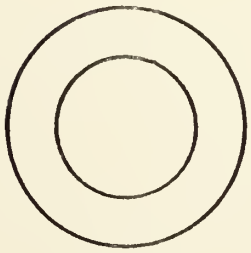
APPENDIX B

SYMBOLS USED IN PERT COST PLANNING FLOW CHART

Major milestones and work packages.



Intermediate milestones.



Interfaces.

Minor milestones.

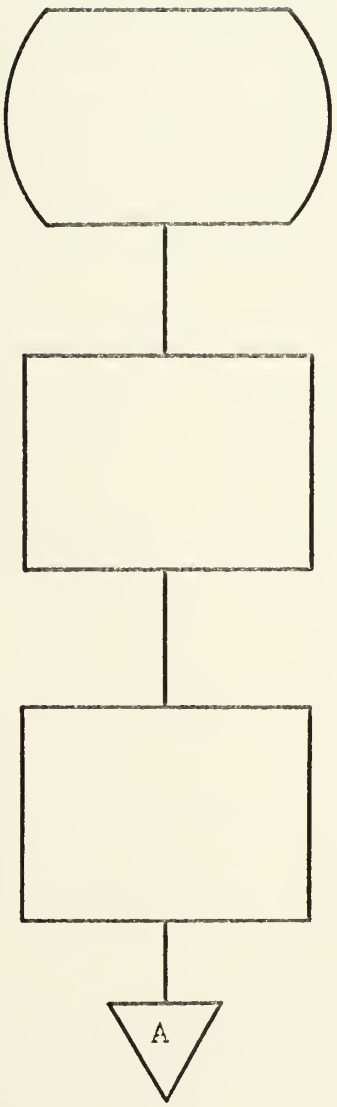
Chart connector: Go to letter indicated.

Network beginning and ending points.

APPENDIX C

PROJECT

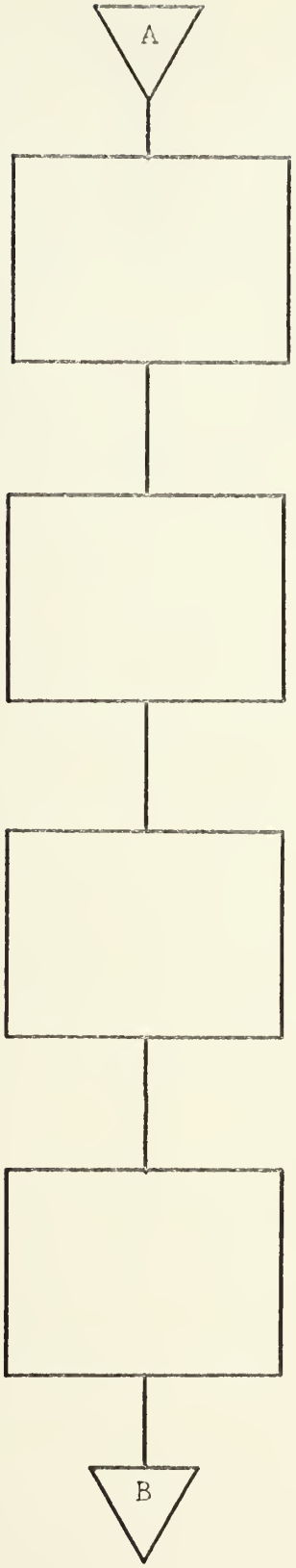
SUMMARY NETWORK



100. Plan started.

300. Situation described.

400. Work breakdown structure developed.

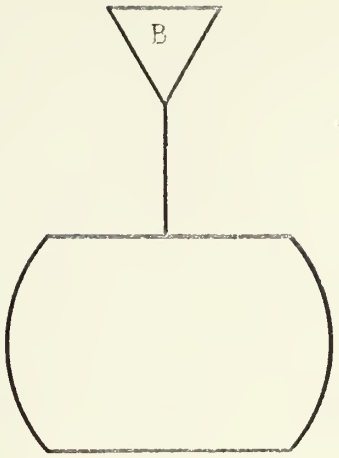


500. All networks constructed.

700. Project summary network normal-crash limits optimized.

1000. Project summary network total cost optimized.

1100. Project control network completed.

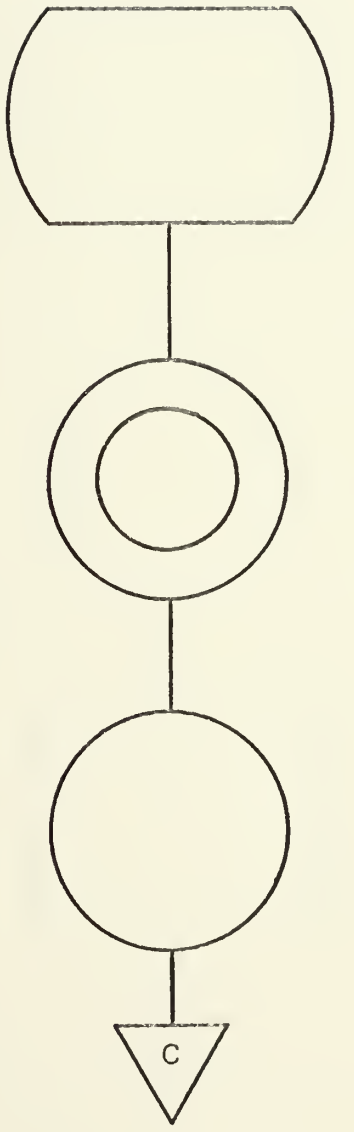


1200. Plan completed.

APPENDIX D

PROJECT

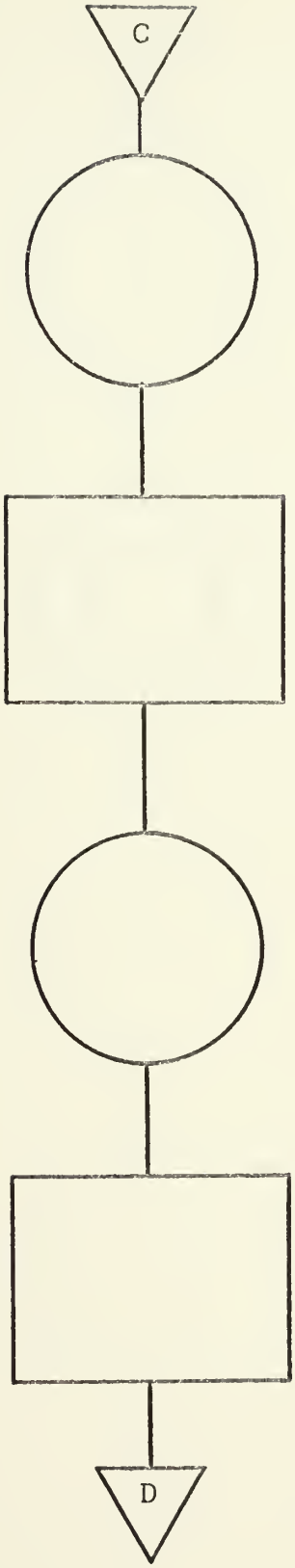
CONTROL NETWORK



100. Plan started.

150. Objective defined.

190. Constraints identified.

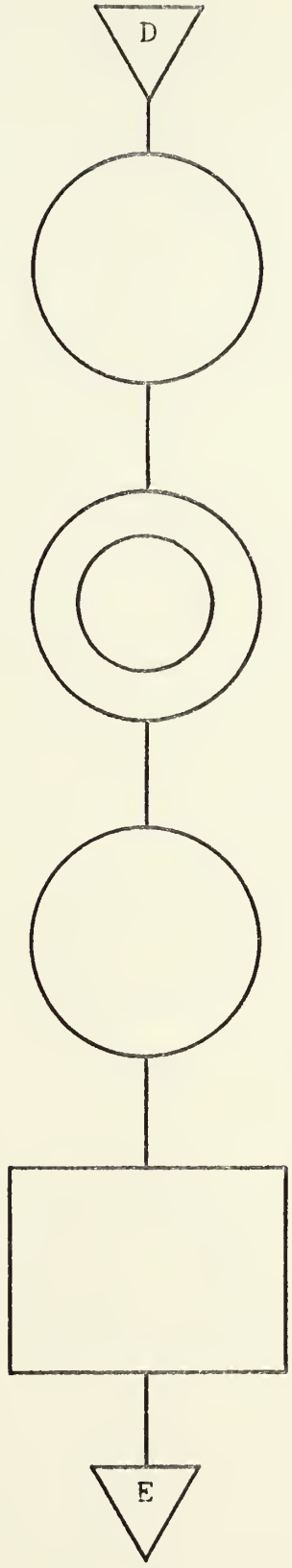


230. Performance indices defined.

300. Situation described.

360. Basic project organization defined.

400. Work breakdown structure developed.

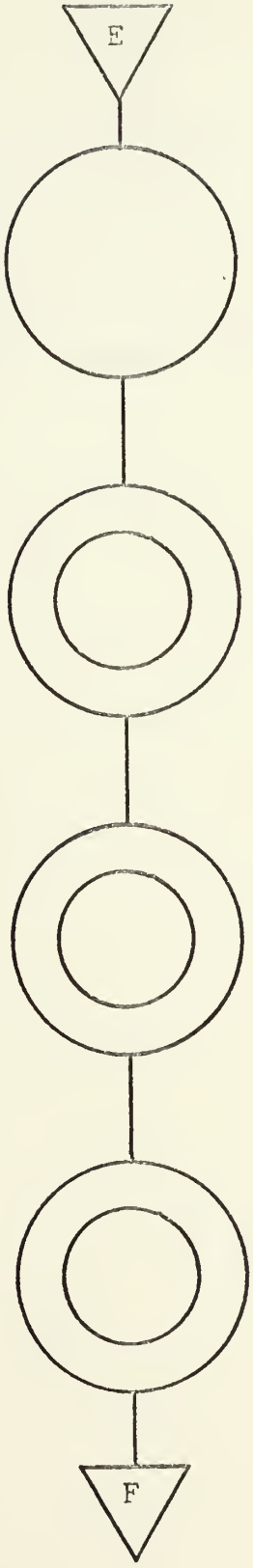


410. Project summary network constructed.

460. Project control network constructed.

490. Work package networks constructed.

500. All networks constructed.

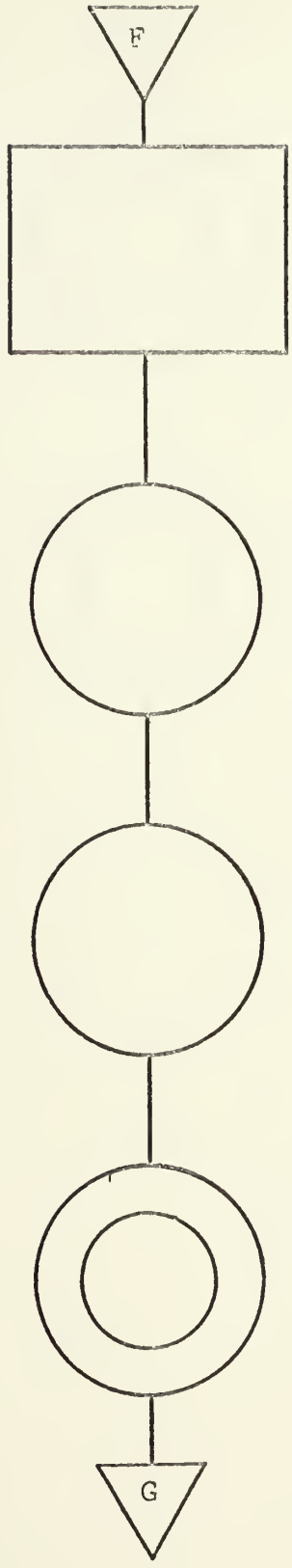


540. Activity normal-crash limits optimized.

580. Minor work package normal-crash limits optimized.

620. Intermediate work package normal-crash limits optimized.

660. Major work package normal-crash limits optimized.

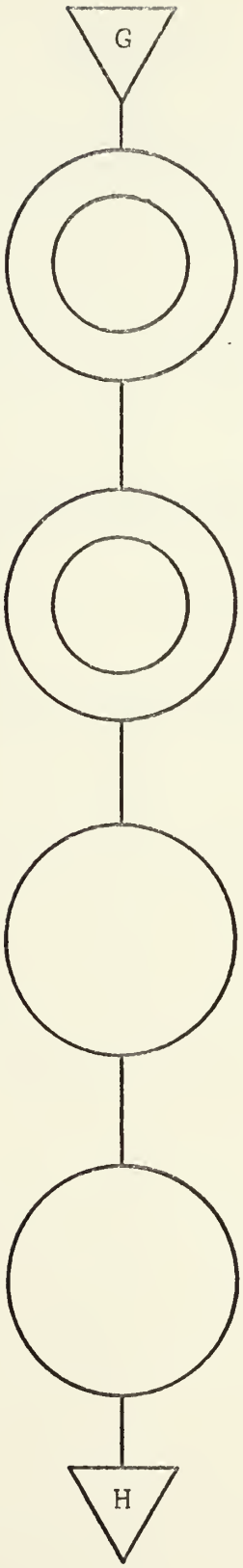


700. Project summary network normal-crash limits optimized.

740. Project summary network direct limit optimized.

760. Project summary network variable non-direct plus penalty costs optimized.

770. Project summary network fixed non-direct plus penalty costs determined.

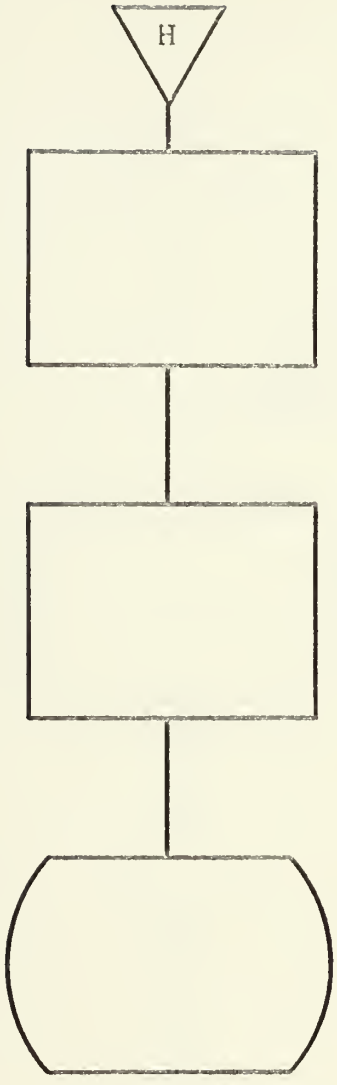


810. Major work packages direct limit optimized.

850. Intermediate work package direct limit optimized.

890. Minor work packages direct limit optimized.

930. Activities direct limit optimized.



1000. Project summary network total cost optimized.

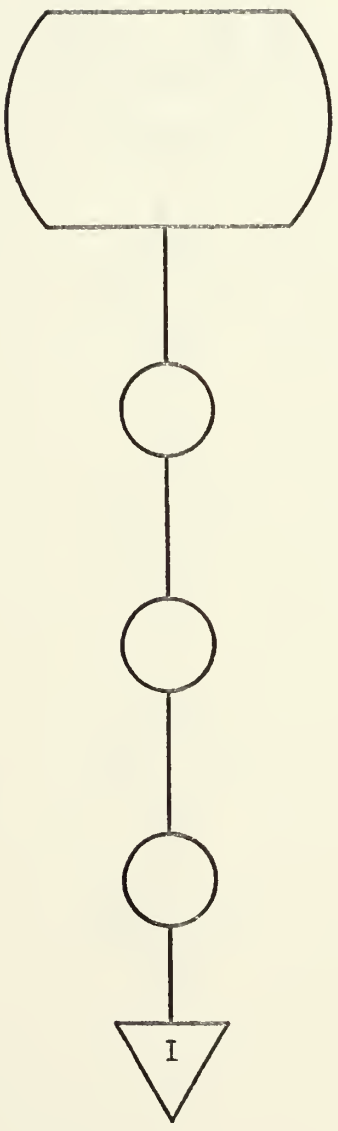
1100. Project control network completed.

1200. Plan completed.

APPENDIX E

MAJOR WORK PACKAGE

DESCRIBE THE SITUATION

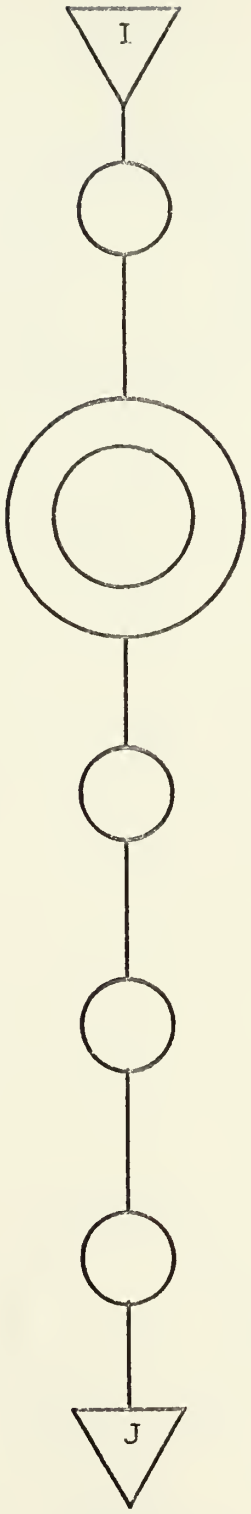


100. Plan started.

110. Objective identified.

120. Physical characteristics determined.

130. Operational characteristics determined.



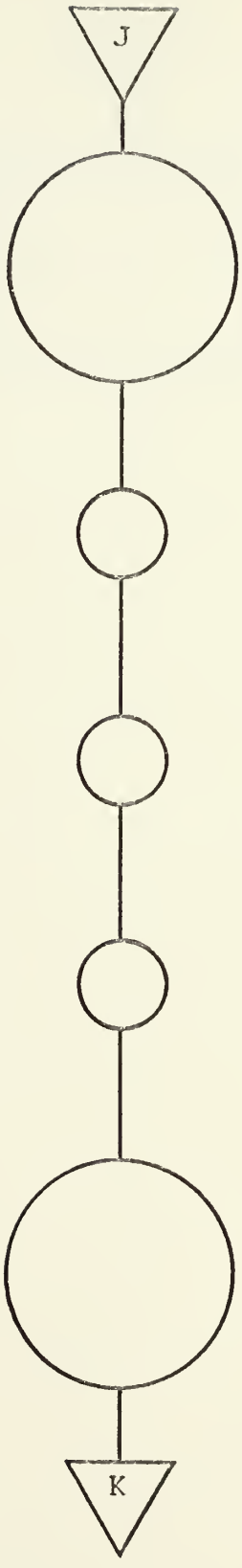
140. Quantity to be produced determined.

150. Objective defined.

160. Time constraints identified.

170. Resource constraints identified.

180. Dollar constraints identified.



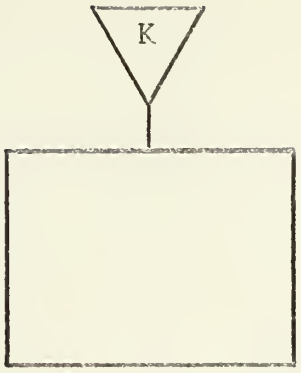
190. Constraints identified.

210. Time performance indices defined.

220. Resource performance indices defined.

230. Cost performance indices defined.

240. Performance indices defined.

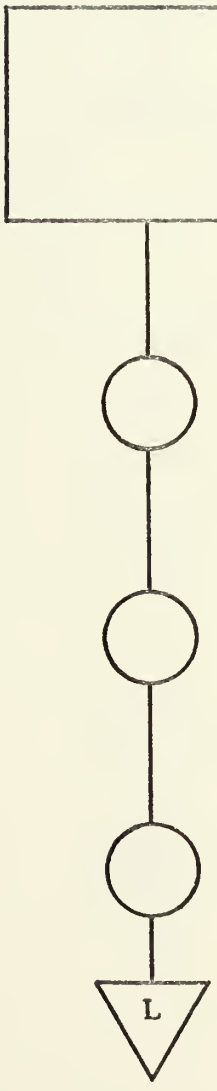


300. Situation described.

APPENDIX F

MAJOR WORK PACKAGE

DEVELOP WORK BREAKDOWN STRUCTURE

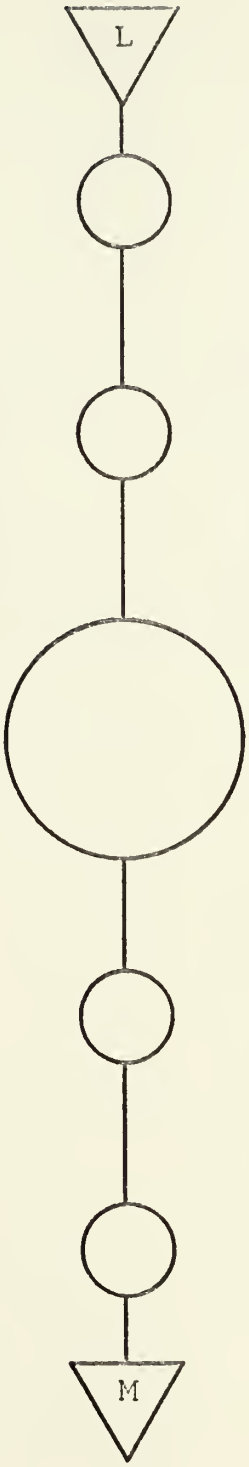


300. Situation described.

310. End product hierarchy constructed.

320. Supporting products added to hierarchy.

330. Supporting services added to hierarchy.



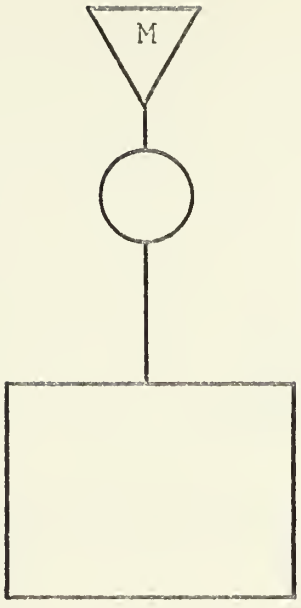
340. Personnel organization correlated with hierarchy.

350. Accounting system correlated with hierarchy.

360. Basic project organization defined.

370. Major, intermediate, and minor milestones defined.

380. Major, intermediate, and minor work packages defined.



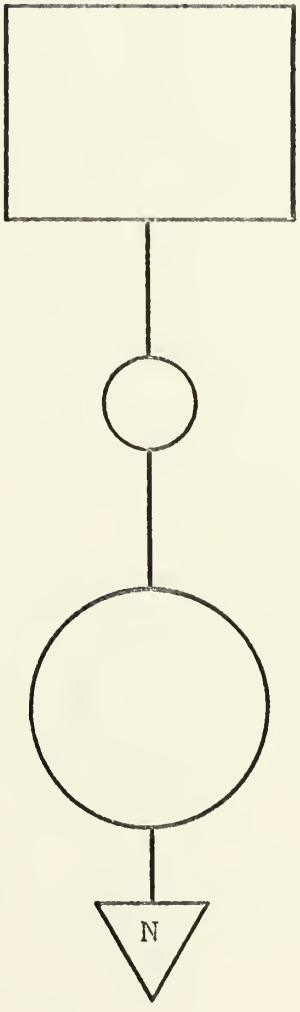
390. Interfaces identified.

400. Work Breakdown Structure developed.

APPENDIX G

MAJOR WORK PACKAGE

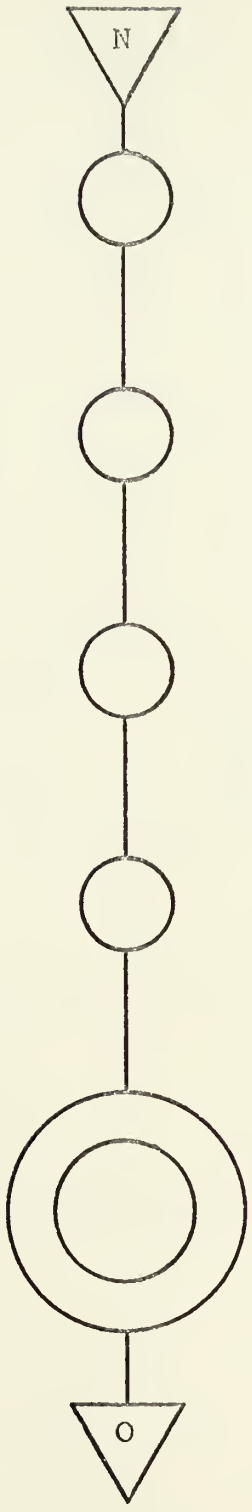
CONSTRUCT ALL NETWORKS



400. Work Breakdown Structure developed.

405. Major milestone network constructed.

410. Project summary network constructed.



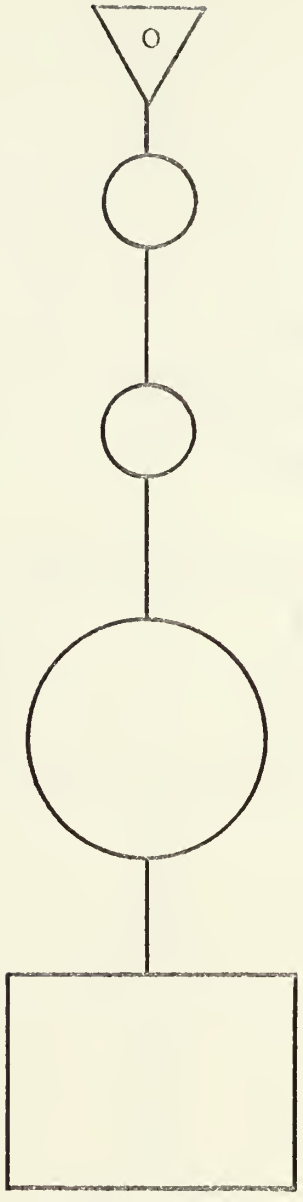
420. Major milestone network constructed.

430. Intermediate milestones added.

440. Interfaces added.

450. Work package responsibility added.

460. Project control network constructed.



470. Major work package networks constructed.

480. Intermediate work package networks constructed.

490. Minor work package networks constructed.

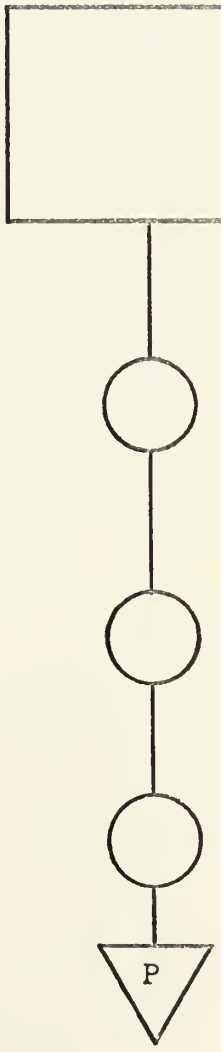
500. All networks constructed.

APPENDIX H

MAJOR WORK PACKAGE

OPTIMIZE PROJECT SUMMARY NETWORK

NORMAL-CRASH LIMITS

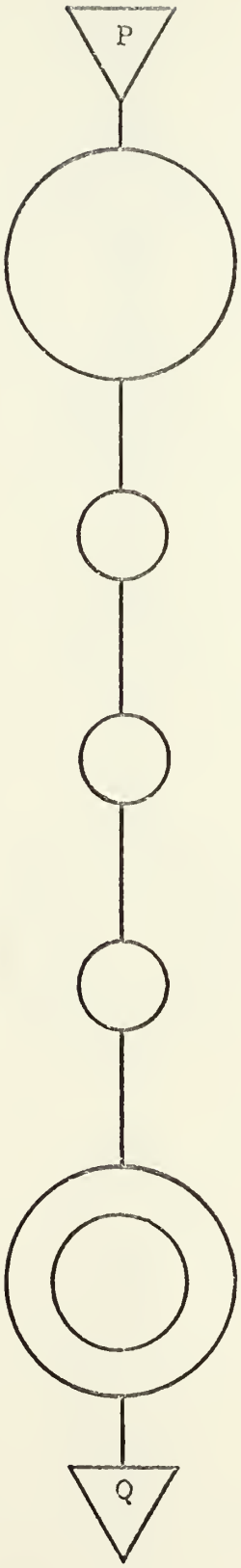


500. All networks constructed.

510. Activity normal-crash resources determined.

520. Activity normal-crash time determined.

530. Activity normal-crash costs determined.



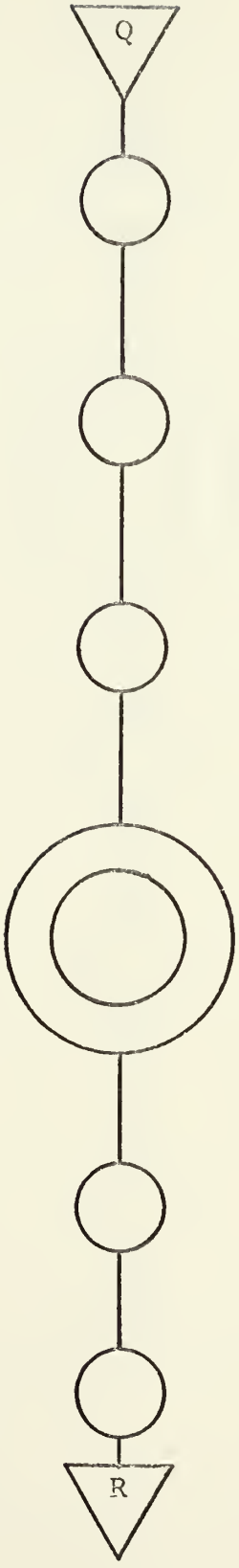
540. Activity normal-crash limits optimized.

550. Minor work package normal-crash times analyzed.

560. Minor work package normal-crash resources analyzed.

570. Minor work package normal-crash costs analyzed.

580. Minor work package normal-crash limits optimized.



590. Intermediate work package normal-crash times analyzed.

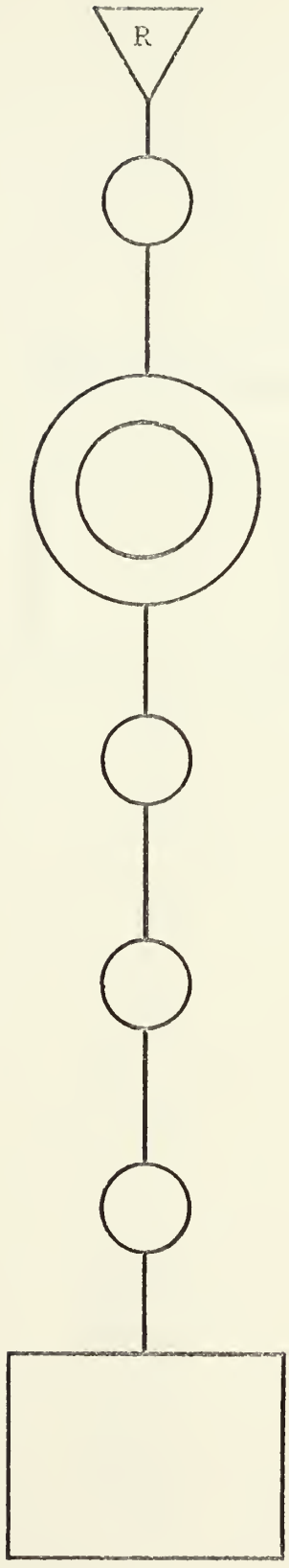
595. Intermediate work package normal-crash resources analyzed.

610. Intermediate work package normal-crash costs analyzed.

620. Intermediate work package normal-crash limits optimized.

630. Major work package normal-crash times analyzed.

640. Major work package normal-crash resources analyzed.



650. Major work package normal-crash costs analyzed.

660. Major work package normal-crash limits optimized.

670. Project summary network normal-crash time analyzed.

680. Project summary network normal-crash resources analyzed.

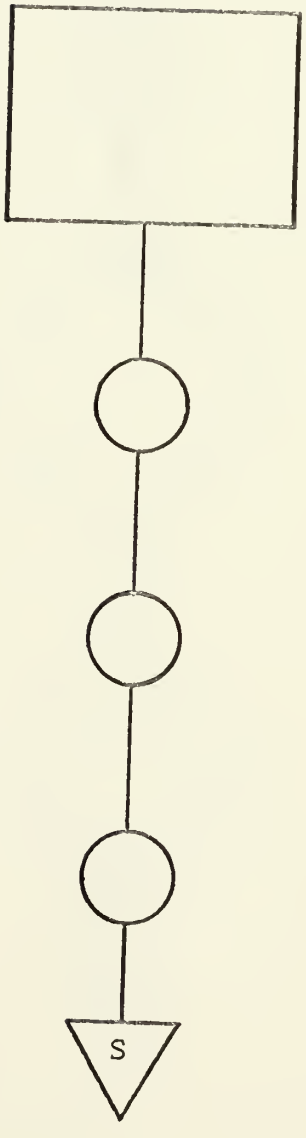
690. Project summary network normal-crash costs analyzed.

700. Project summary network normal-crash limits optimized.

APPENDIX I

MAJOR WORK PACKAGE

OPTIMIZE PROJECT SUMMARY NETWORK TOTAL COST

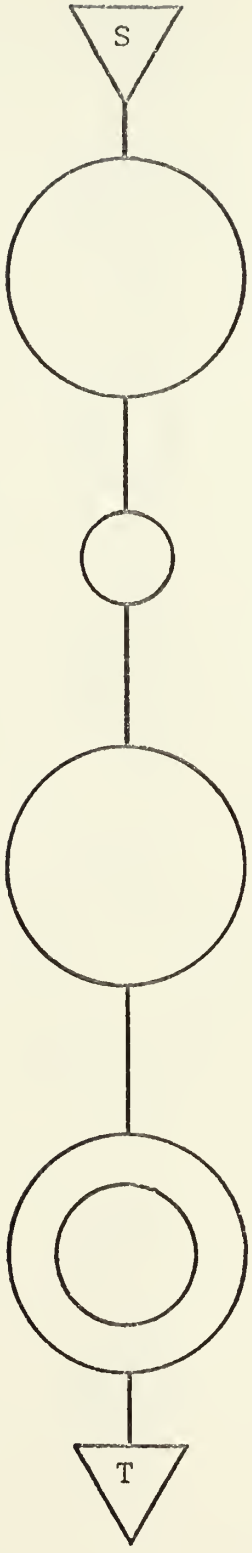


700. Project summary network normal-crash limits optimized.

710. Project summary network direct time analyzed.

720. Project summary network direct resources analyzed.

730. Project summary network direct cost analyzed.

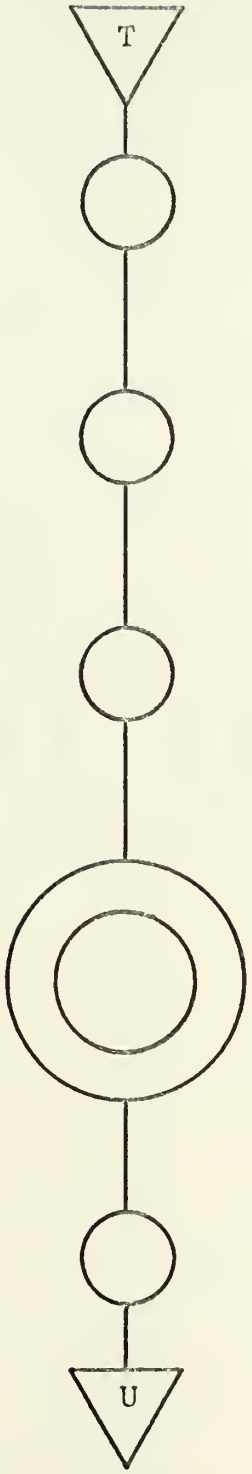


740. Project summary network direct limit optimized.

750. Project summary network variable non-direct plus penalty costs analyzed.

760. Project summary network variable non-direct plus penalty costs optimized.

770. Project summary network fixed non-direct plus penalty costs determined.



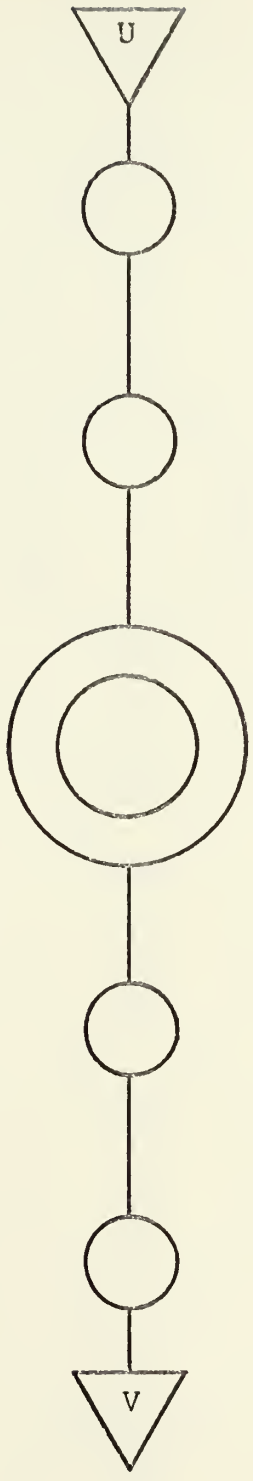
780. Major work package direct time analyzed.

790. Major work package direct resources analyzed.

805. Major work package direct cost analyzed.

810. Major work package direct limits optimized.

820. Intermediate work package direct time analyzed.



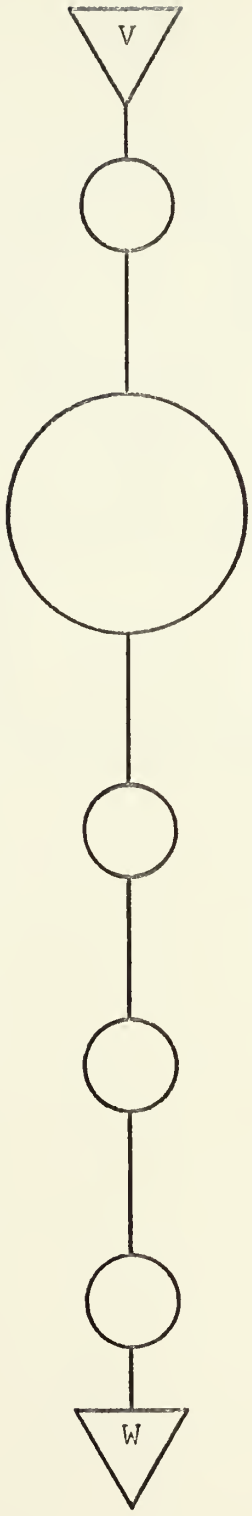
830. Intermediate work package direct resources analyzed.

840. Intermediate work package direct cost analyzed.

850. Intermediate work package direct limit optimized.

860. Minor work package direct time analyzed.

870. Minor work package direct resources analyzed.



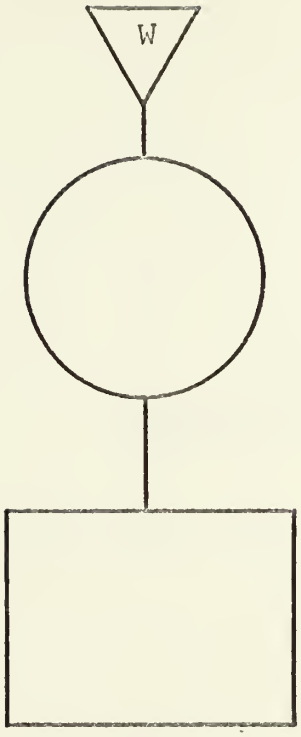
880. Minor work package direct cost analyzed.

890. Minor work package direct limit optimized.

905. Activity direct time analyzed.

910. Activity direct time analyzed.

920. Activity direct resources analyzed.



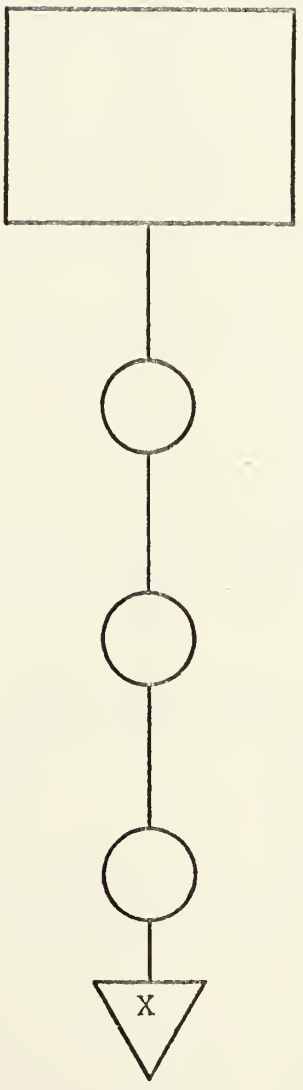
930. Activity direct limit optimized.

1000. Project summary network total cost optimized.

APPENDIX J

MAJOR WORK PACKAGE

COMPLETE PROJECT CONTROL NETWORK

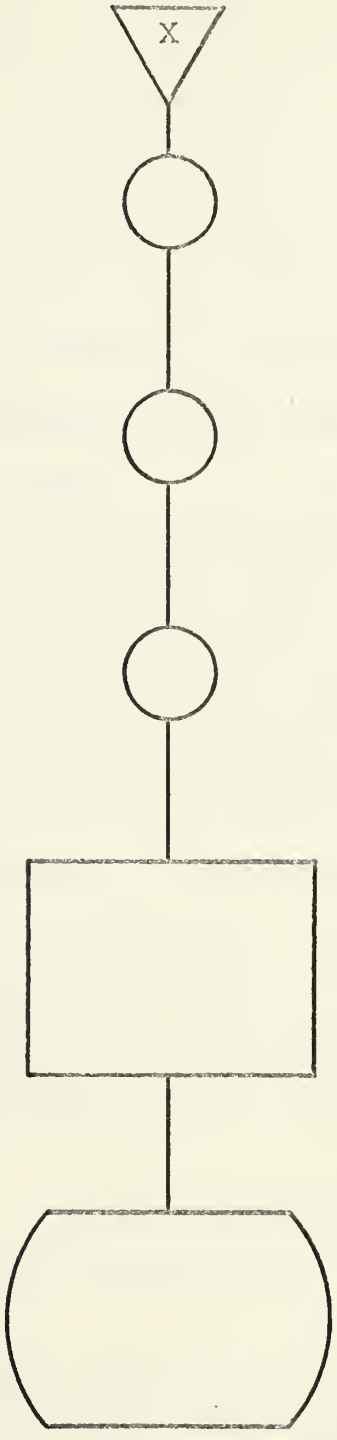


1000. Project summary network total cost optimized.

1010. Project control network reviewed and revised.

1020. Project control network milestone and interface time and cost data annotated.

1030. Project control network direct time limit analyzed.



1040. Project control network direct cost analyzed.

1050. Project control network direct limit optimized.

1060. Project summary network updated.

1100. Project control network completed.

1200. Plan completed.

SELECTED BIBLIOGRAPHY

Archibald, Russell D. and Villoria, Richard L. Network-Based Management Systems (PERT/CPM). New York: John Wiley & Sons, Inc., 1967.

This is a textbook approach to management familiarization, implementation, and application of CPM and PERT network systems. There are only general ideas presented on the use of PERT COST. However, the majority of the book sets PERT systems into a realistic perspective within the large organization. The manager's responsibility is fully discussed and demonstrated by walk-through examples. About half of the book gives actual case studies from government and business on the application of PERT systems. There is a selected bibliography on pp. 466-70.

Federal Electric Corporation. PERT COST: A Programmed Instruction Manual. New Jersey: Federal Electric Corporation, 1964.

This is a programmed text which takes a general look at the procedures and techniques of PERT up through PERT COST. The information and examples are based on government procedures.

Horowitz, Joseph. Critical Path Scheduling: Management Control Through CPM and PERT. New York: The Ronald Press Company, 1967.

This book gives an excellent description of the mechanics involved in using CPM and PERT. Numerous illustrations and examples, requiring only elementary arithmetic or simple graphs are used to demonstrate the principles and techniques.

The use of Costs with the network is well analyzed, but the costs are "given" with no discussion of how they are obtained or what changes have to be made in the basic network to accommodate cost analysis. There is a bibliography on pp. 213-15.

Levin, Richard I., Ph.D. and Kirkpatrick, Charles A., D.C.S. Planning and Control with PERT/CPM. New York: McGraw-Hill Book Company, 1966.

The emphasis of this book is on the mechanical aspects of PERT from the user's point of view. It takes the reader from the historical development of PERT networks up through the PERT TIME concept. There is a bibliography on pp. 158-66.

Miller, Robert W. Schedule, Cost, and Profit Control with PERT: A Comprehensive Guide for Program Management. New York: McGraw-Hill Book Company, Inc., 1963.

The focus of this book is on upper management's understanding of the background, development, techniques, implementation, use on projects, and the effect on the organization and profits of PERT.

PERT COST is developed on the model used by DOD and NASA. It gives a good discussion of the work breakdown structure and cost package criteria. There is a representative bibliography on pp. 203-6.

Moder, Joseph J. and Phillips, Cecil R. Project Management with CPM and PERT. New York: Reinhold Publishing Corporation, 1964.

A comprehensive discussion of the mechanics of building and analyzing a CPM or PERT network is given. Some parts require some statistics, linear programming, and an understanding of the use of algorithms.

Time vs. cost trade-offs are determined on both an intuitive basis and through the use of linear programming.

Office of the Secretary of Defense and National Aeronautics and Space Administration. DOD and NASA Guide: PERT COST Systems Design. Washington, D.C.: U.S. Government Printing Office, 1962.

This is a guide and reference for the implementation and systematic development of PERT/COST. It is the basic reference for most other books on PERT COST. The basic PERT COST management reports are laid out in detail and briefly explained. The entire PERT COST system is outlined and demonstrated through a practical example.